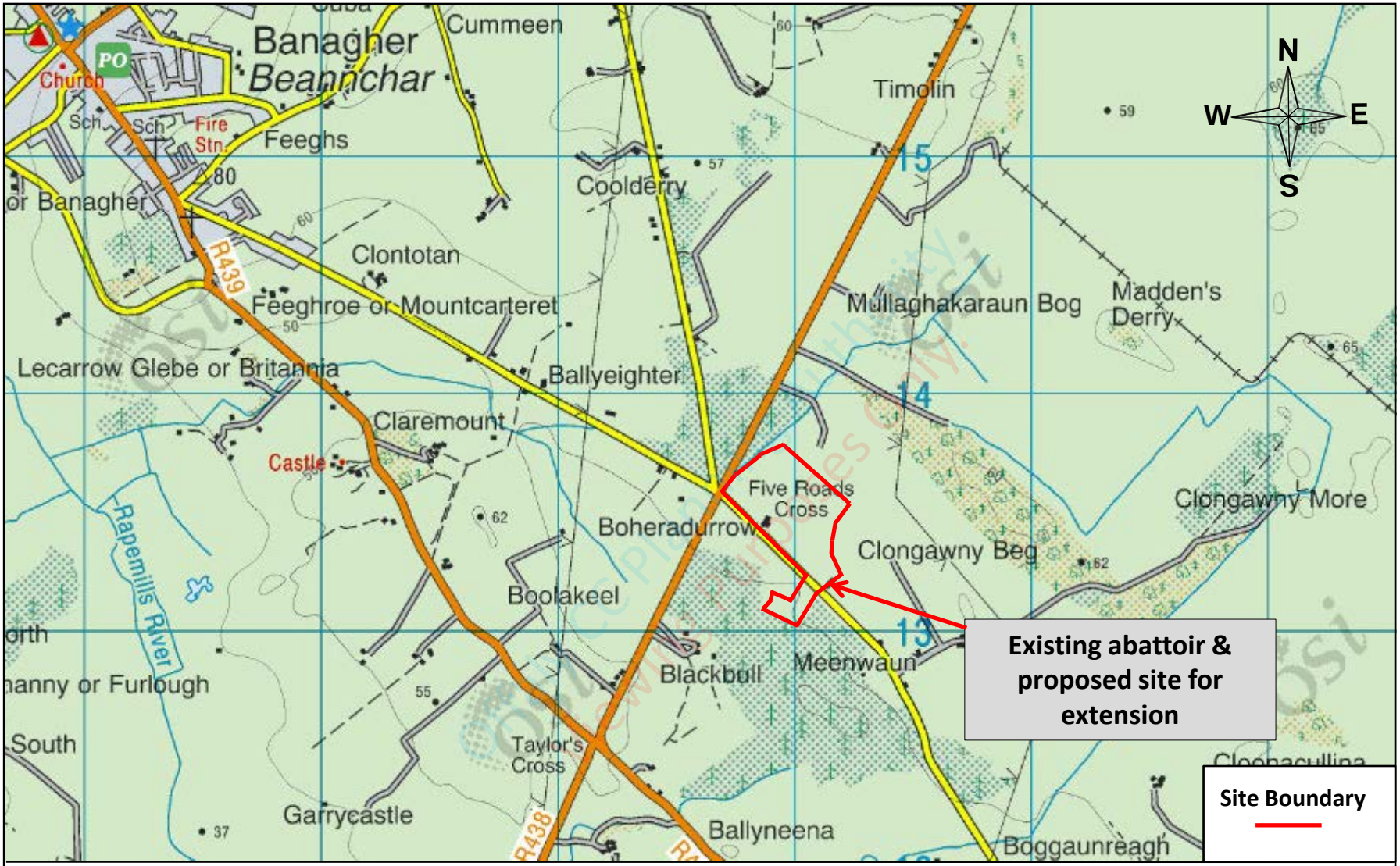
ATTACHMENT 11

- LAND CHAPTER ATTACHMENTS -

ATTACHMENT 11.1

DRAWINGS



IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Site Location and Boundary (OSI, 2019)

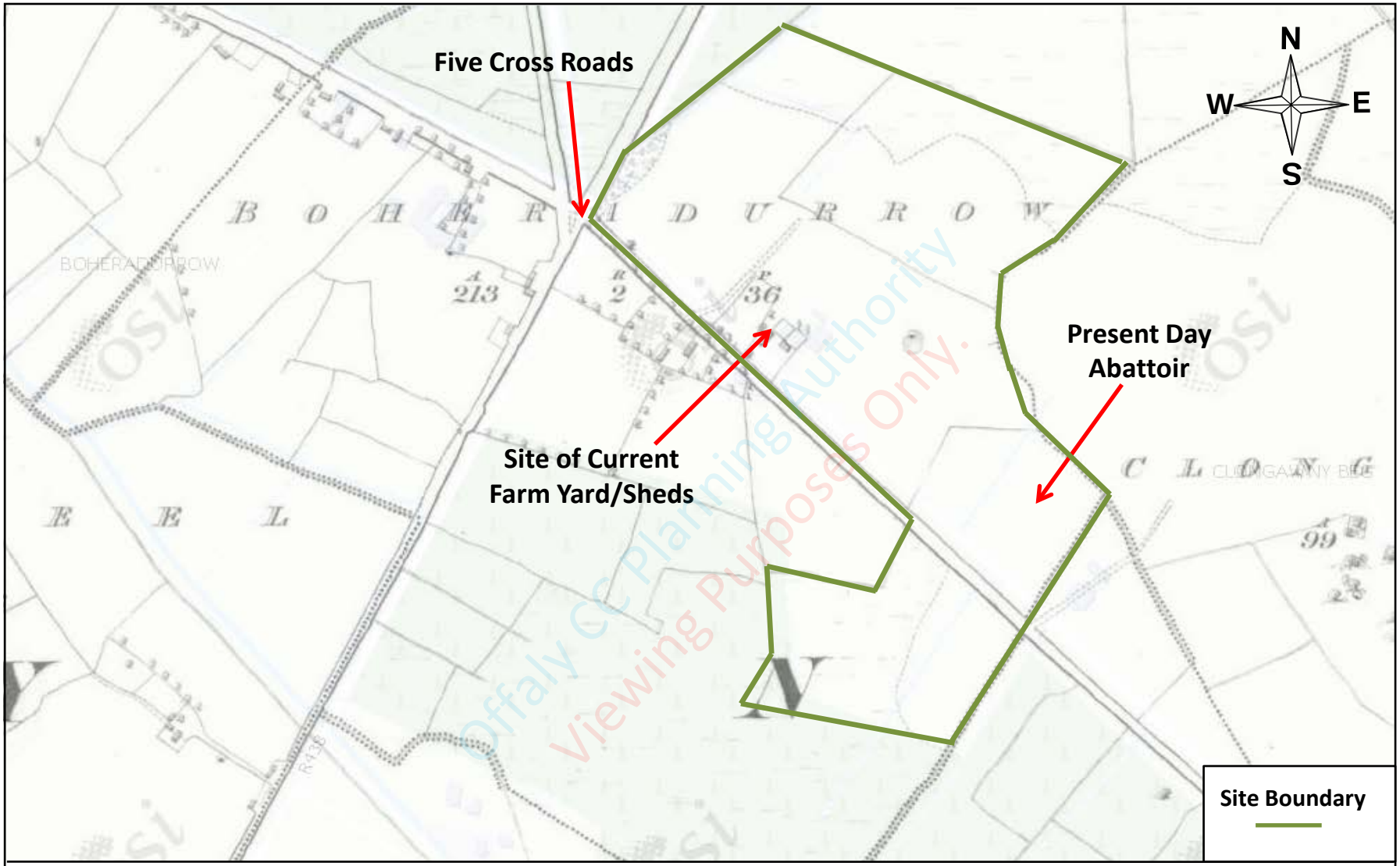
Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-001	IE1746	A	KM

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Aerial Image of the existing abattoir and proposed extension area

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	23/05/2019	IE1746-002	IE1746	B	KM

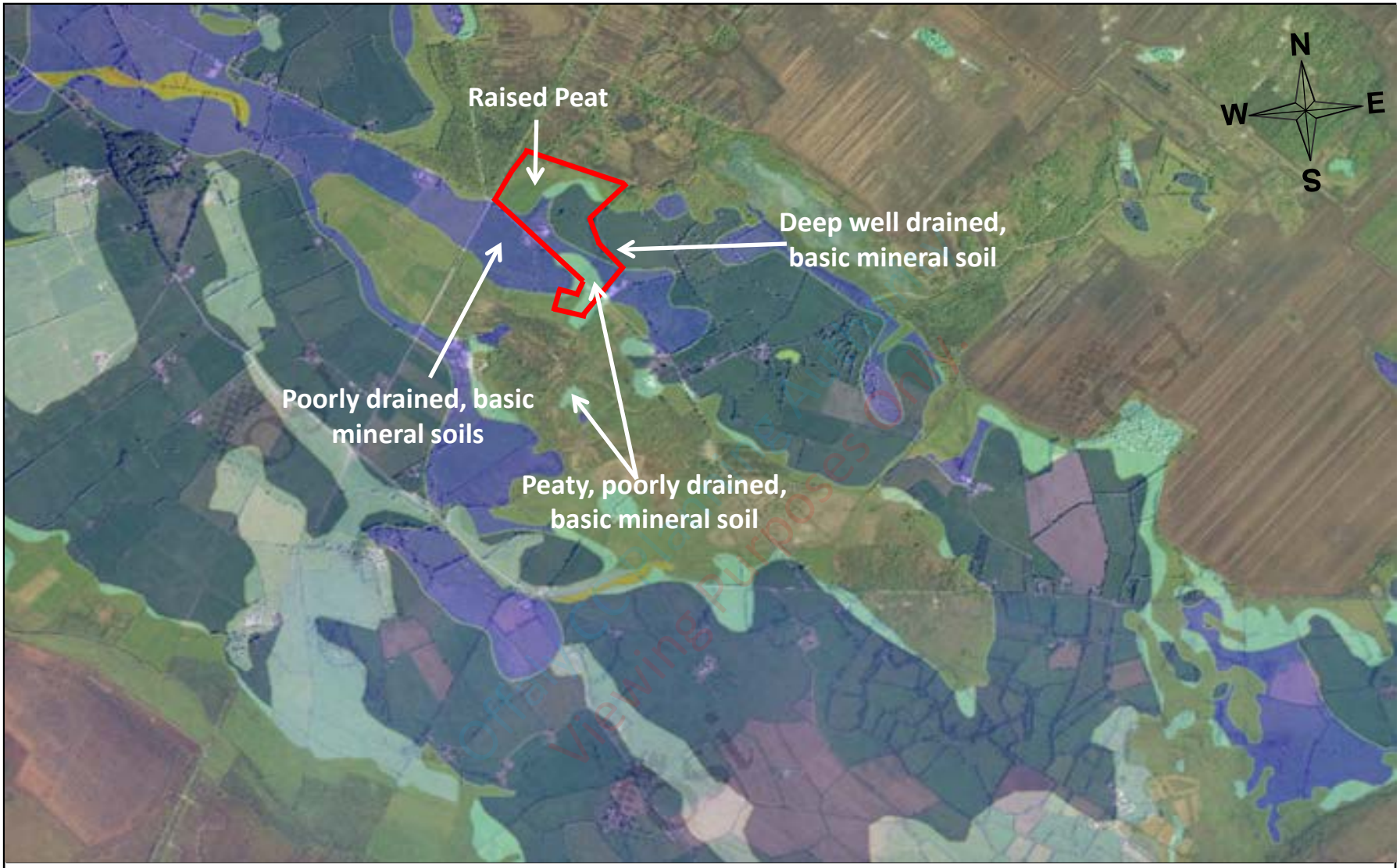


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Historic Map 6 inch Black & White (1837-1842)

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-003	IE1746	A	KM

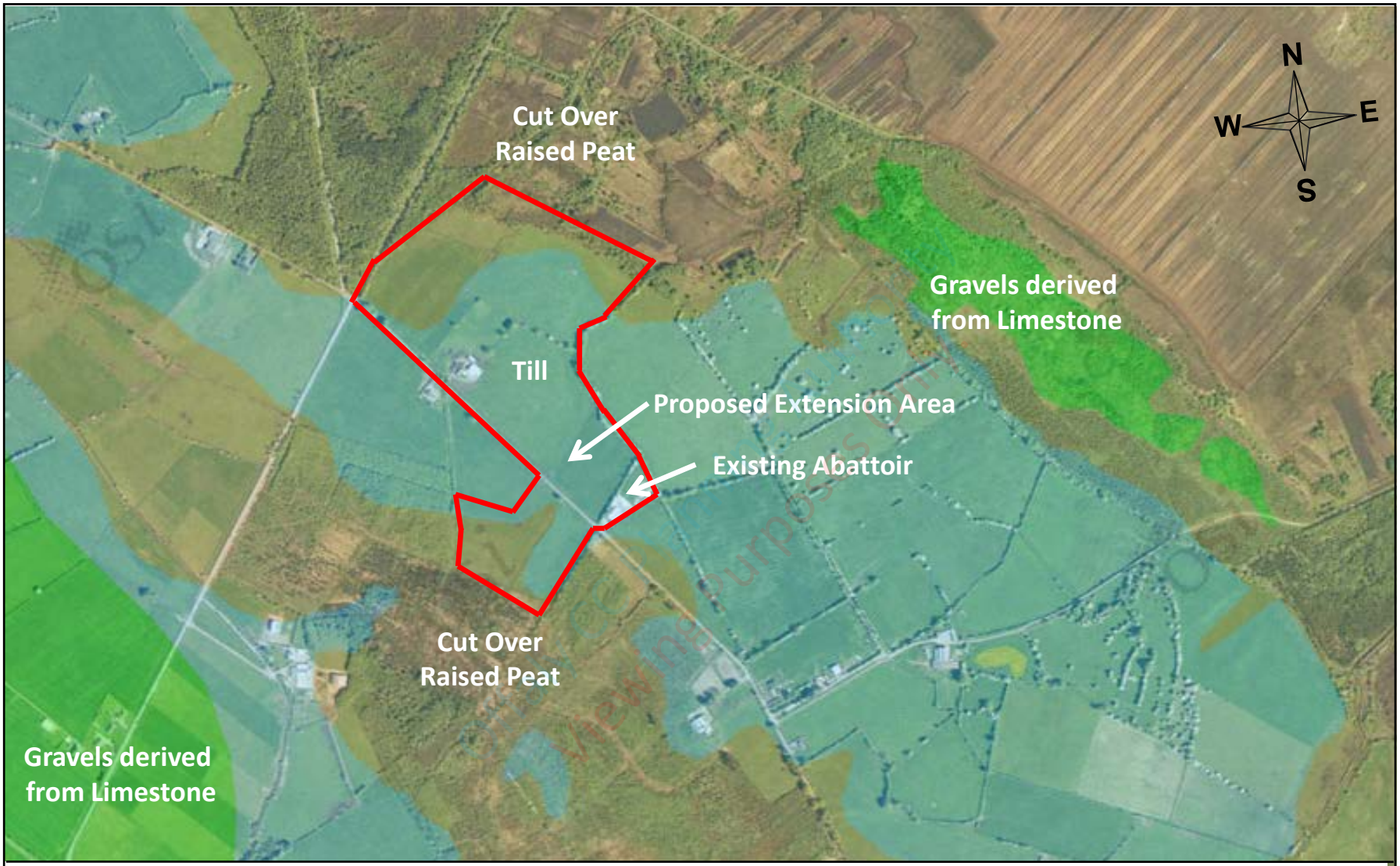


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Regional Soil Mapping (GSI; EPA; Teagasc, 2019)

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-004	IE1746	A	KM

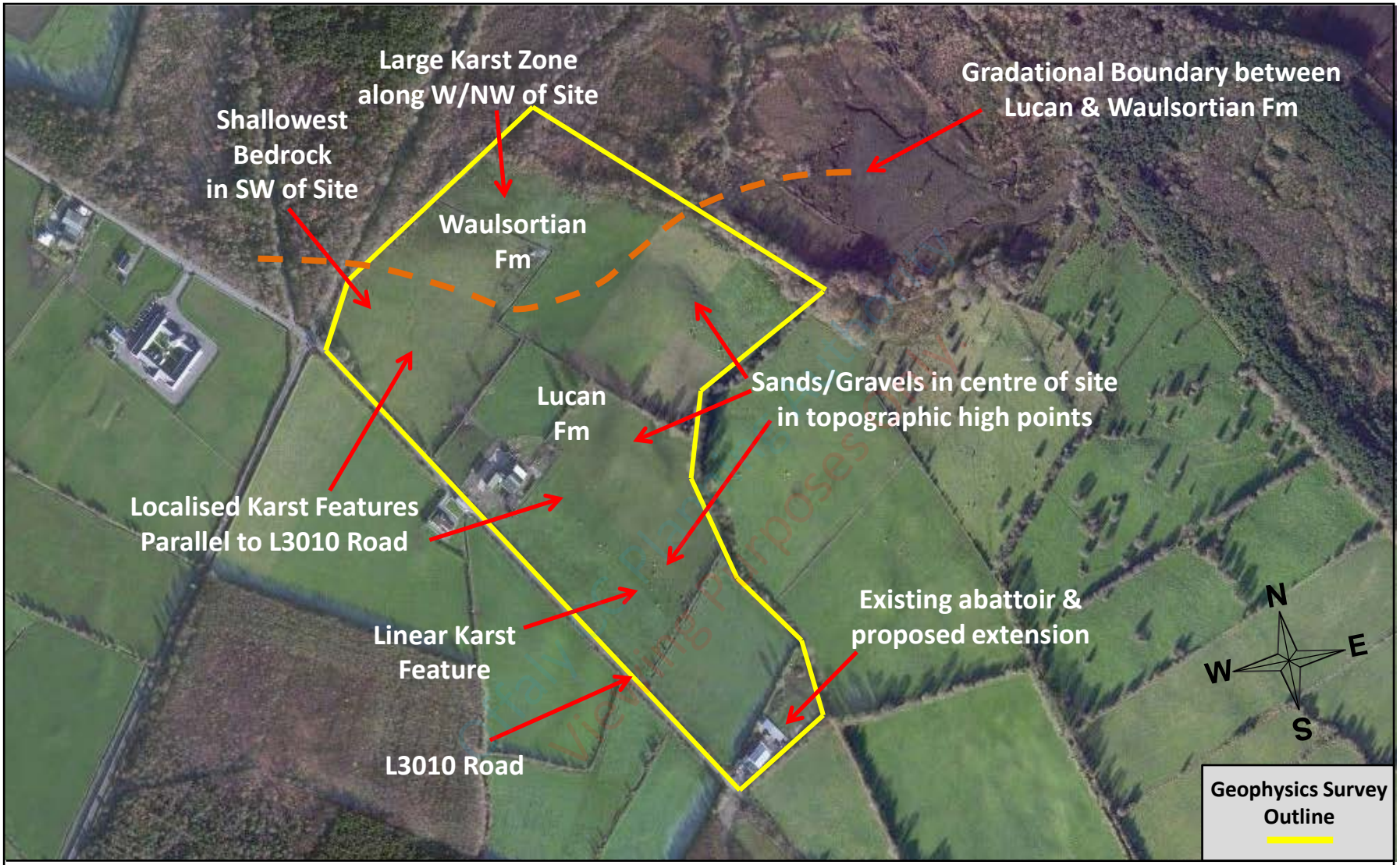


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Regional Subsoil Mapping (GSI, 2019)

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-005	IE1746	A	KM

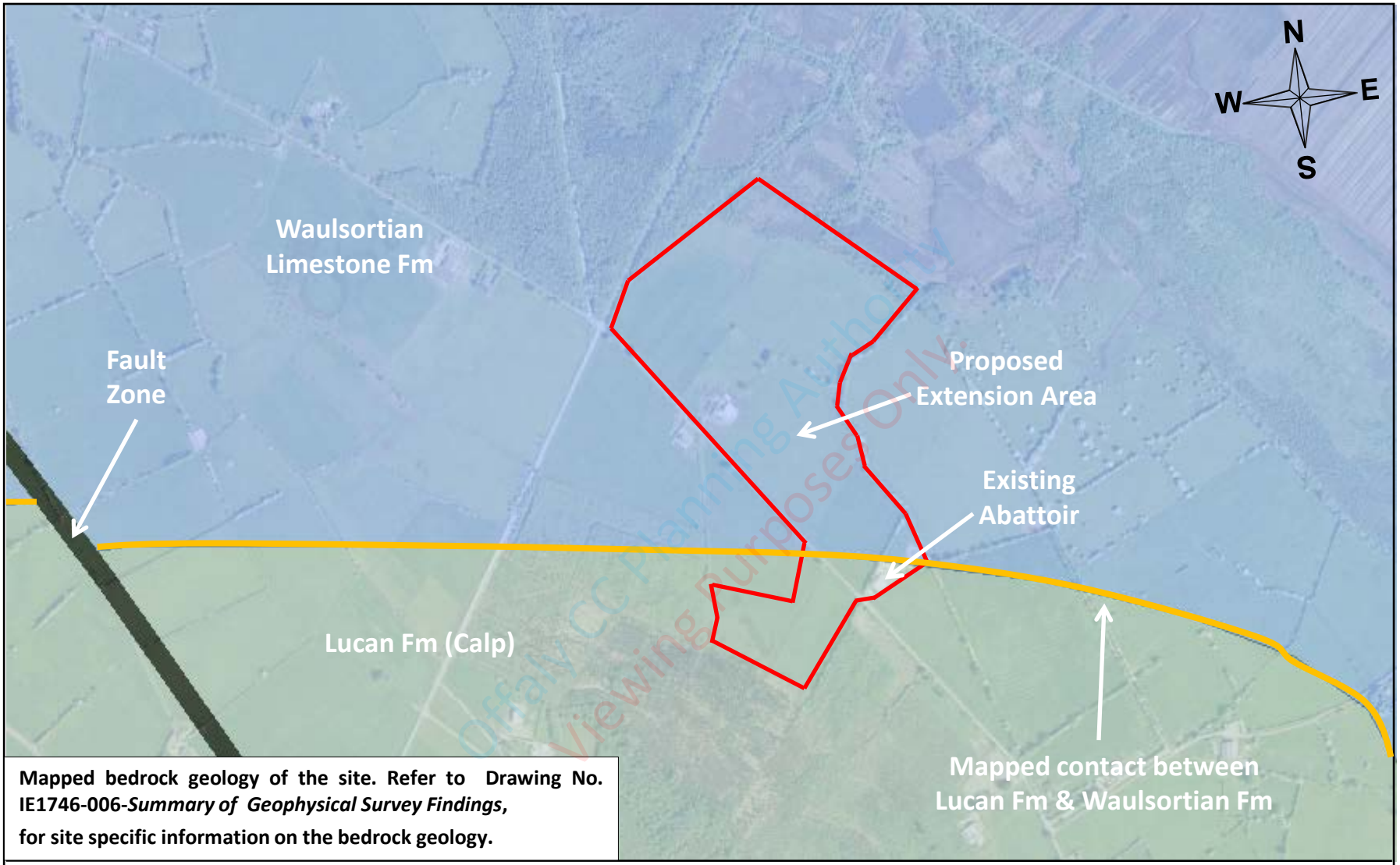


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Summary of Geophysical Survey Findings

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	10/05/2019	IE1746-006	IE1746	B	KM



Mapped bedrock geology of the site. Refer to Drawing No. IE1746-006-*Summary of Geophysical Survey Findings*, for site specific information on the bedrock geology.

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Regional Bedrock & Structural Geology Mapping (GSI, 2019)

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-007	IE1746	A	KM

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Geological Heritage (GSI, 2019)

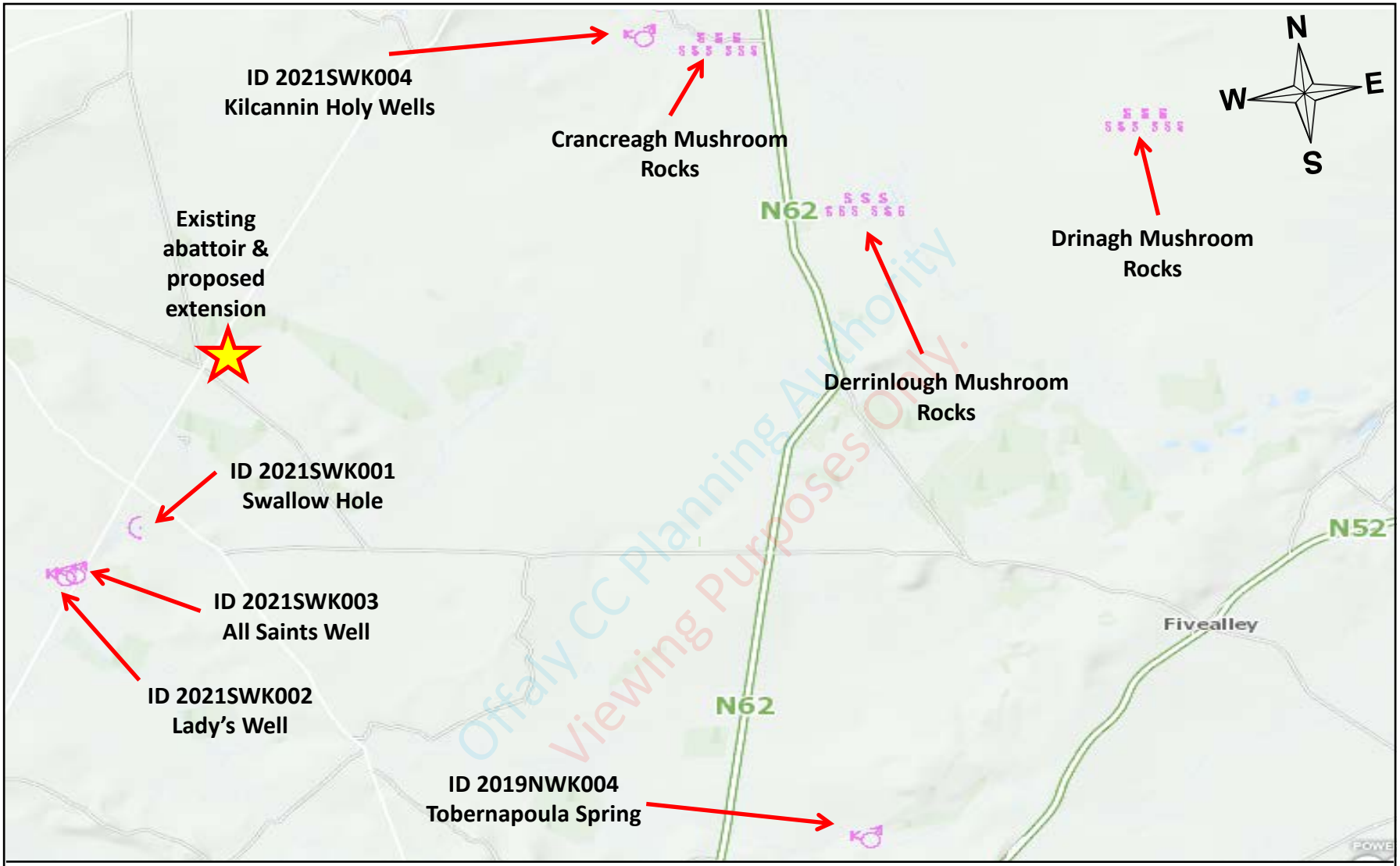
Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-008	IE1746	A	KM

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Landslides (GSI, 2019)

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-009	IE1746	A	KM

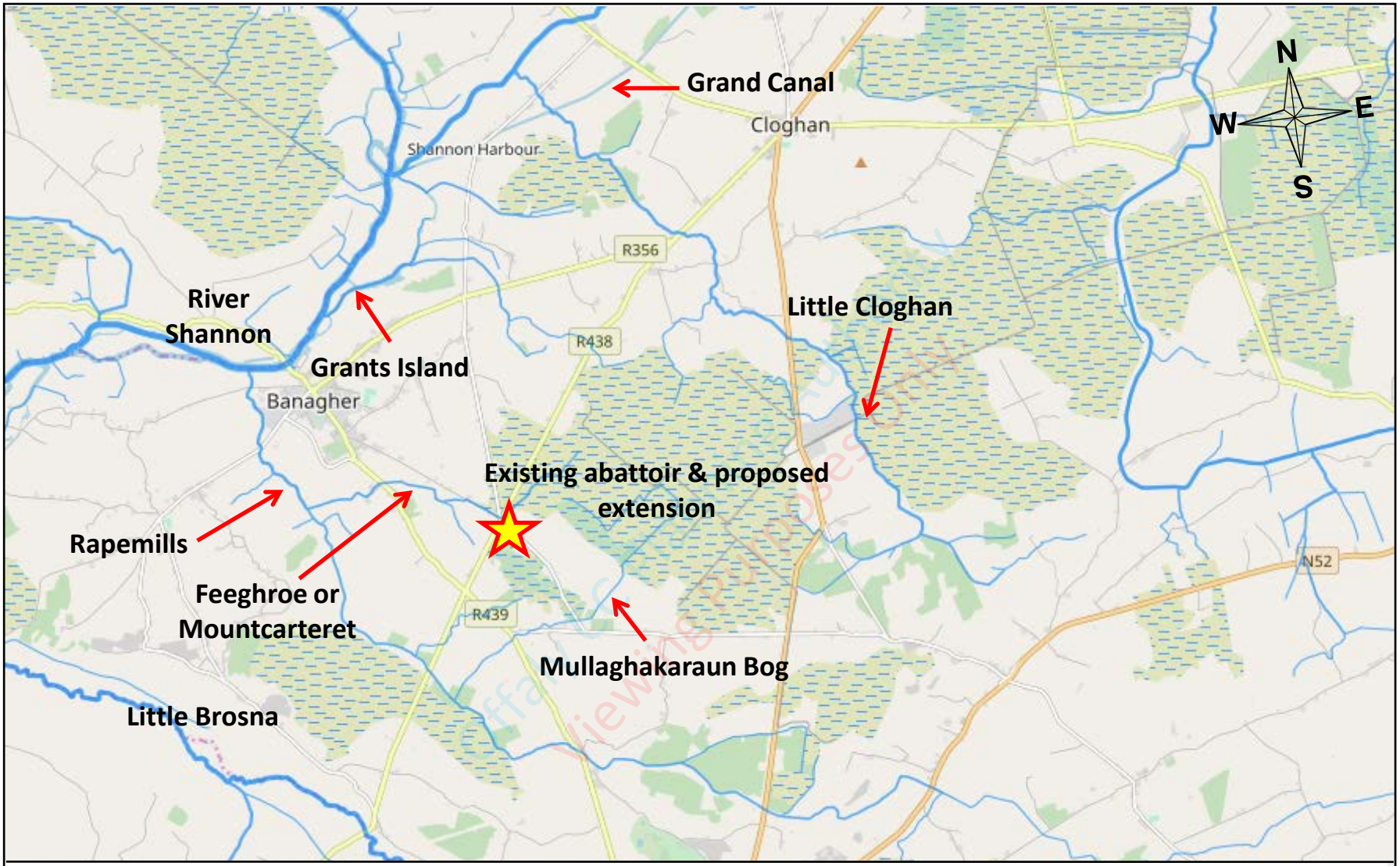


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Regional Karst Features (GSI, 2019)

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-010	IE1746	A	KM

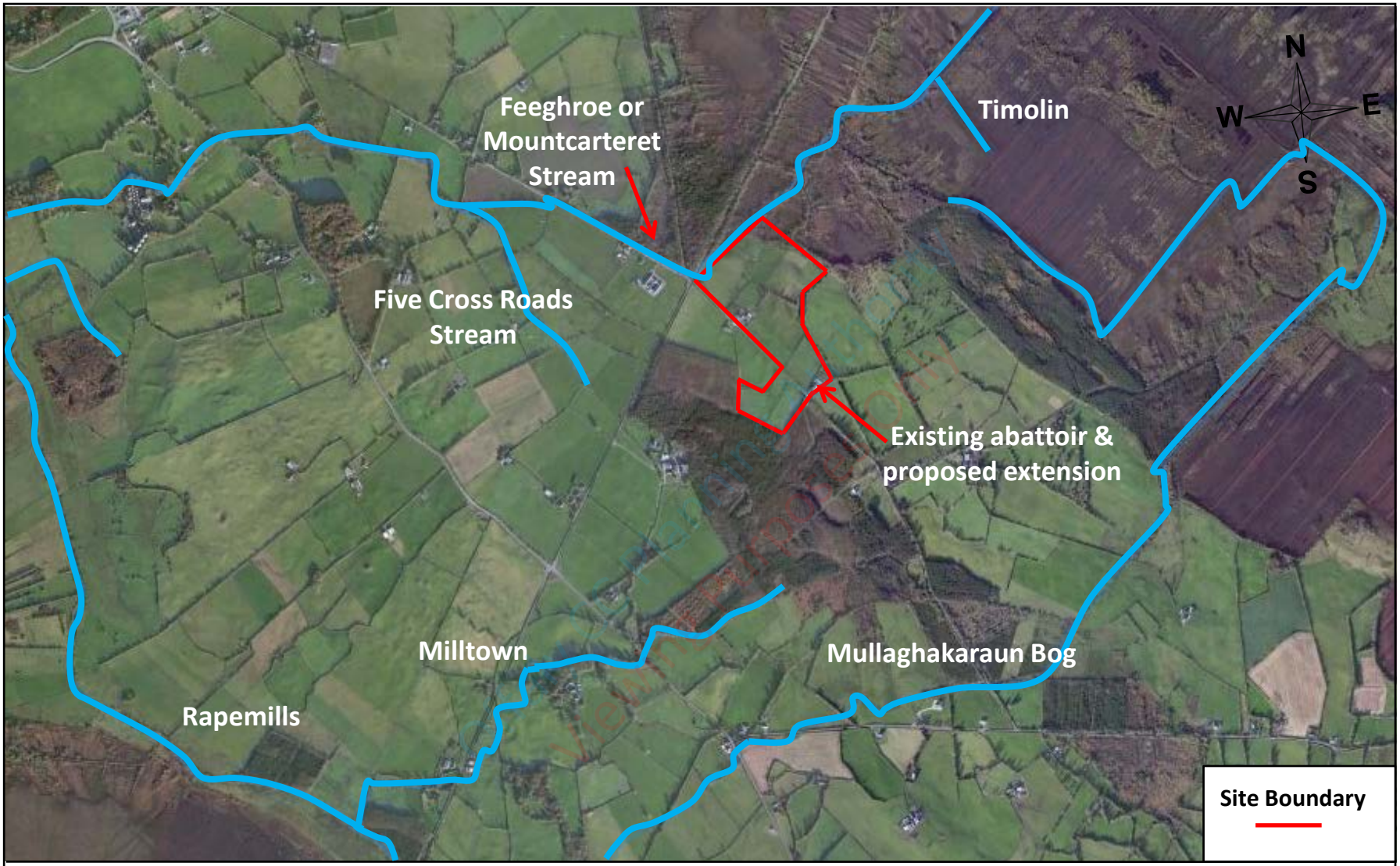


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Regional Surface Water Features (Hydrology) – EPA, 2019

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-011	IE1746	A	KM



IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Local Surface Water Features (Hydrology) – EPA, 2019

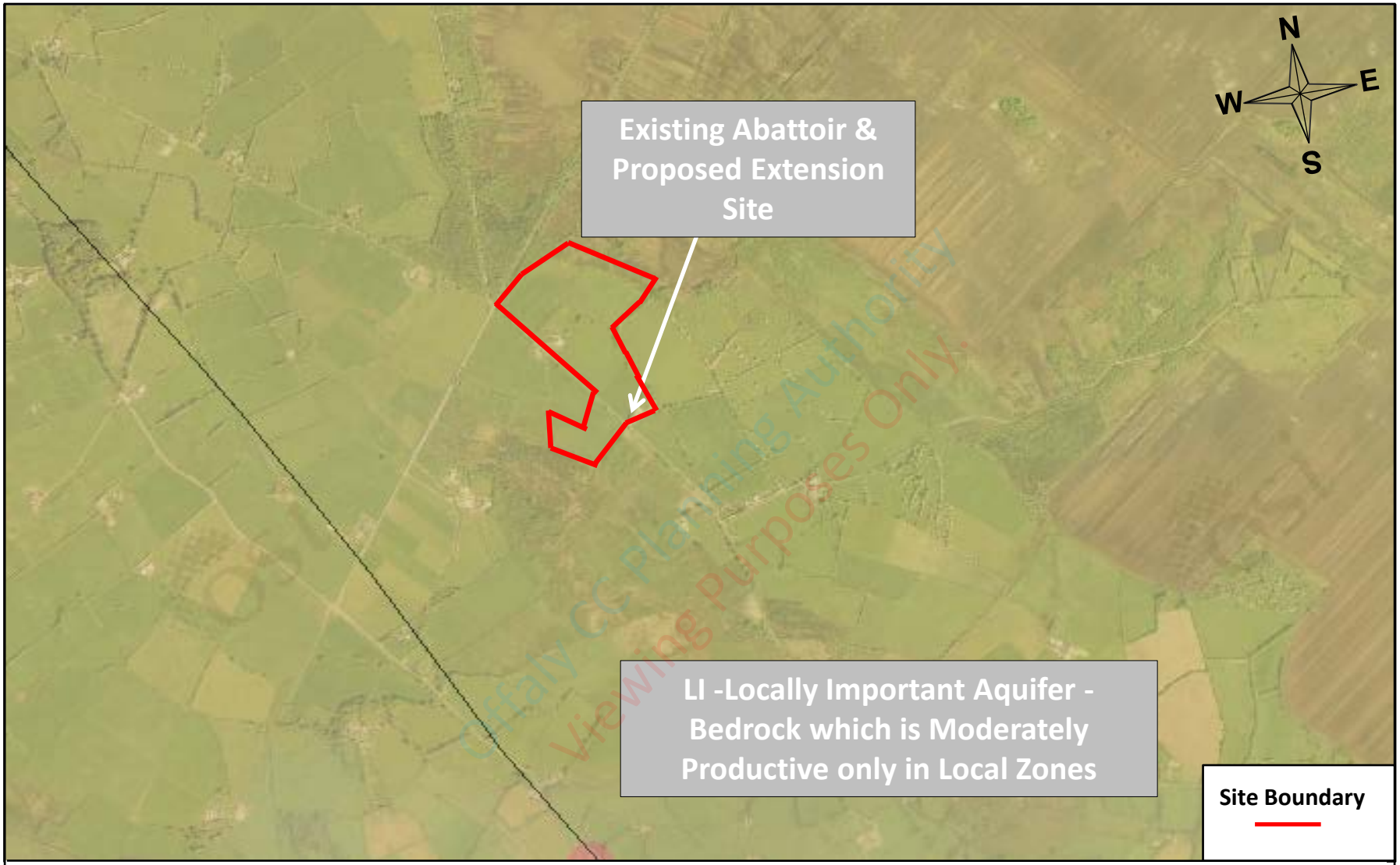
Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-012	IE1746	A	KM

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Drinking Water Rivers – EPA, 2019.

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-013	IE1746	A	KM

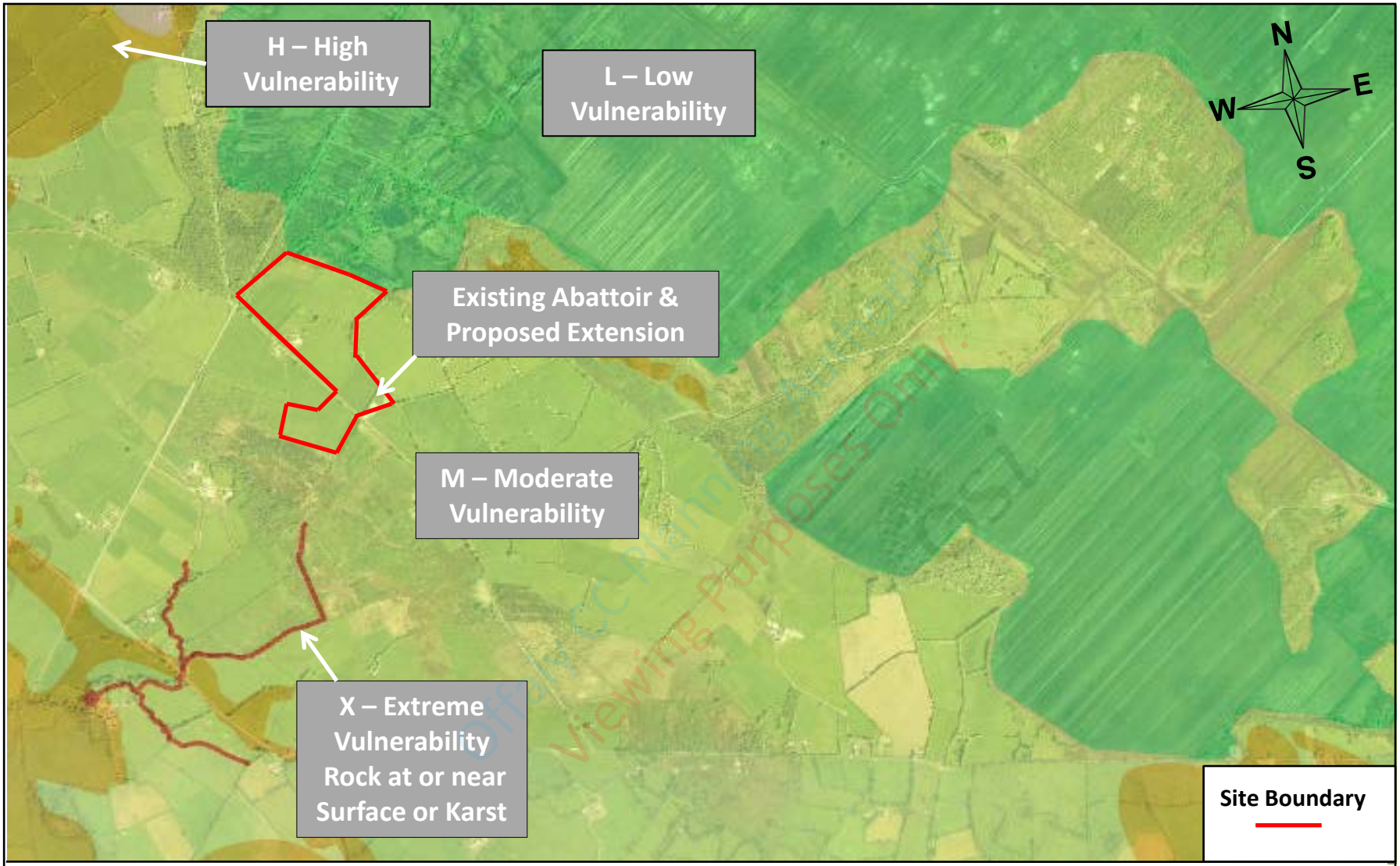


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Regional Hydrogeology – GSI, 2019.

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-014	IE1746	A	KM

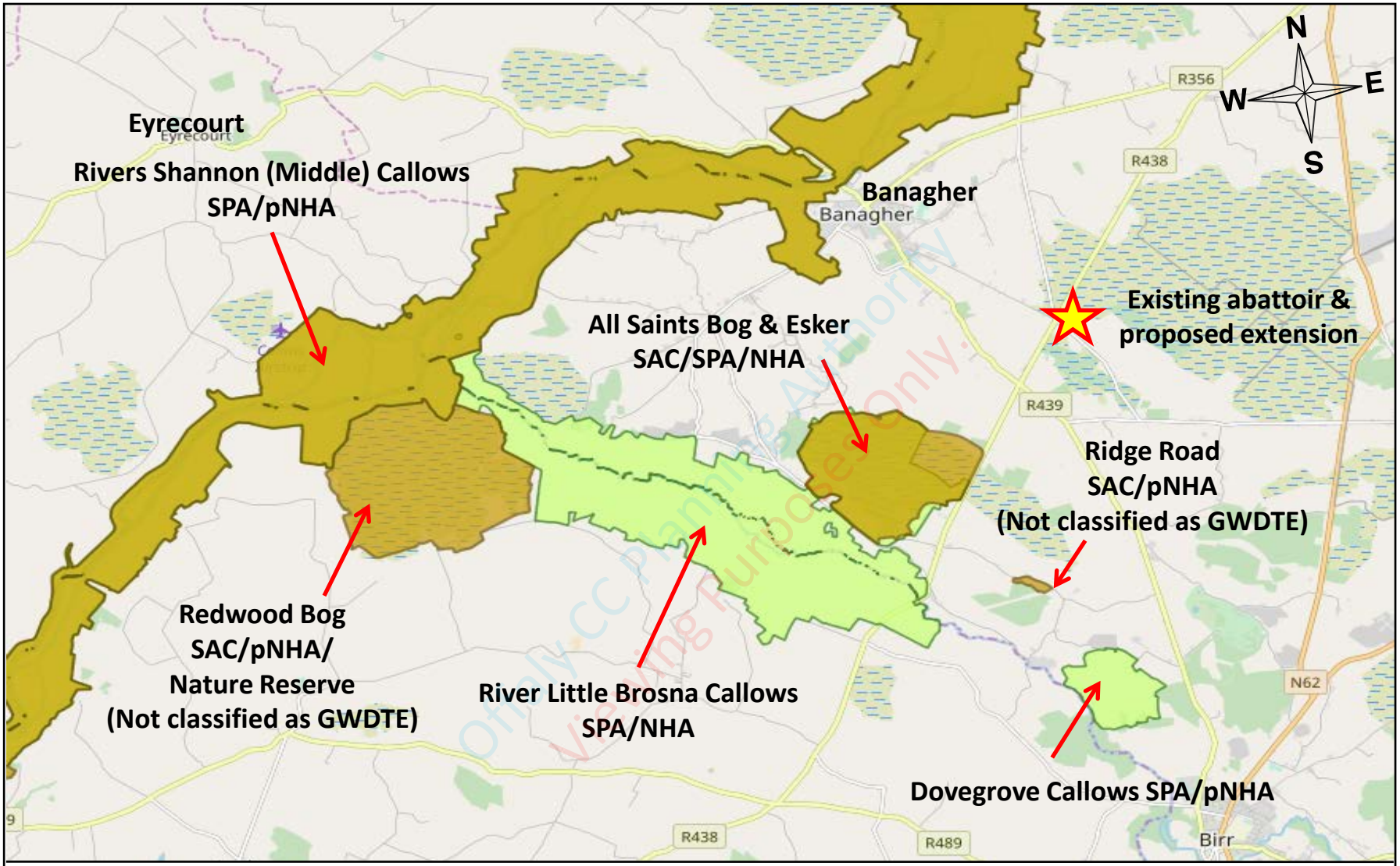


IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Groundwater Vulnerability – GSI, 2019

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-015	IE1746	A	KM



IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Groundwater Dependent Terrestrial Ecosystems (EPA ,2019)

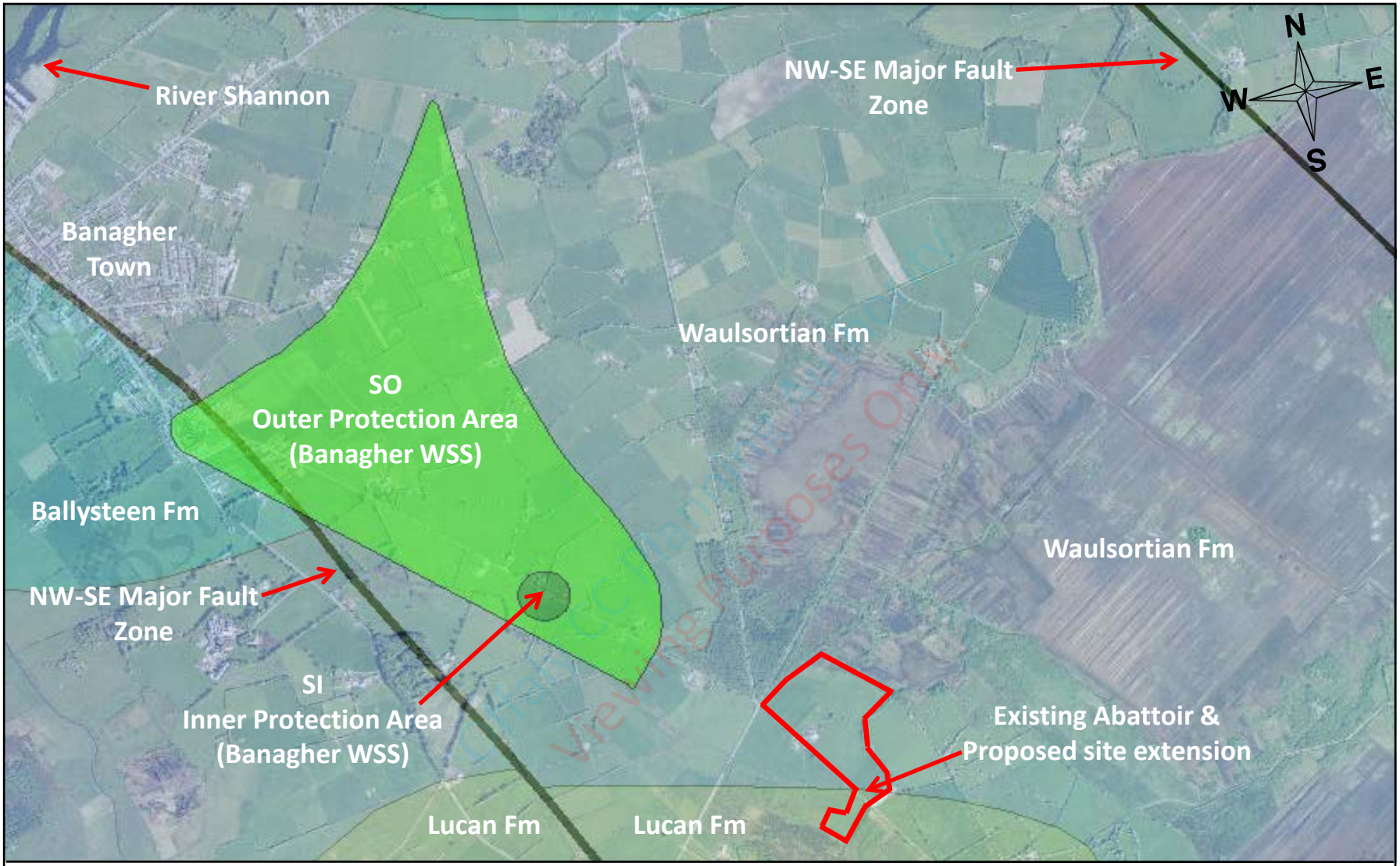
Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-016	IE1746	A	KM

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Groundwater in SAC Habitats (EPA, 2019).

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-017	IE1746	A	KM



IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Ltd.
Drg. Title:	Banagher WSS SPZ & Geological Setting

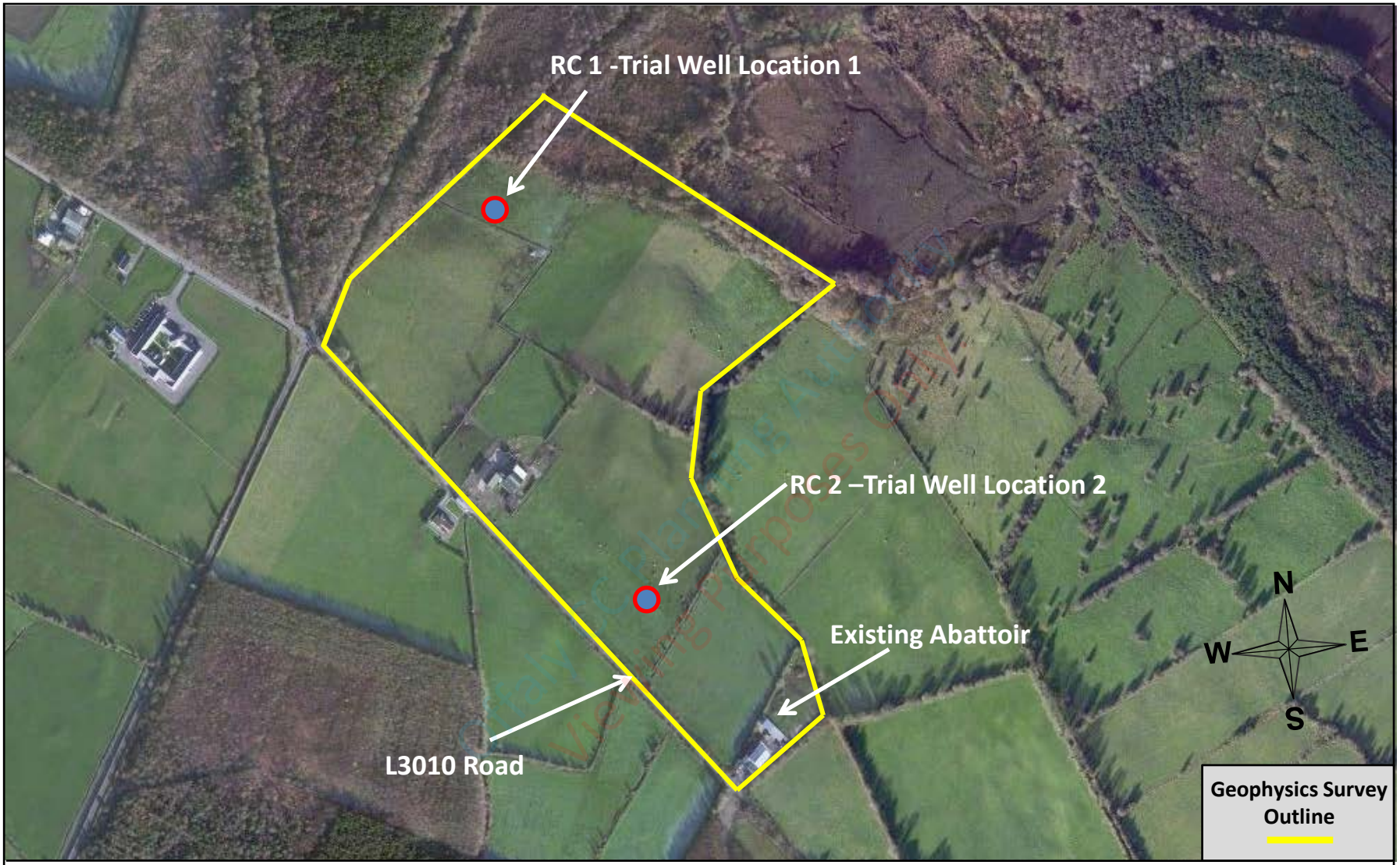
Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	10/05/2019	IE1746-018	IE1746	B	KM

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited
Drg. Title:	Groundwater Abstractions (GSI, 2019).

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	04/03/2019	IE1746-019	IE1746	A	KM



IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	Land, Soil, Geology, Hydrology & Hydrogeology EIAR
Project Address:	Boheradurrow, Banagher, Offaly.
Client:	Banagher Chilling Limited.
Drg. Title:	Potential Trial Well Locations - Identified by Geophysics

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	20/02/2019	IE1746-020	IE1746	A	KM

ATTACHMENT 11.2

CONCEPTUAL MODEL
BANAGHER CHILLING LTD.

Conceptual Model

Banagher Chilling Ltd.

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

IE Consulting
Innovation Centre,
Green Rd.,
Carlow
Ph: 059 9133084
Fax: 059-9140459
E-mail: info@iece.ie

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

Project Title:	EIAR – Land, Soil, Geology, Hydrology & Hydrogeology
Project Address:	Boheradurrow, Banagher, Offaly
Client:	Banagher Chilling Ltd.
Drg. Title:	Regional Cross Section – Line of Section for Conceptual Model

Drg. Scale:	Date:	Dwg No:	Job No:	Revision:	Dwg. By :
NTS	15/05/2019	1746-CM	IE1746	A	KM

Drawing. No 1746-CM

A NW

B SW

Banagher – Clontotan WSS Wells

Sands & Gravels

Proposed Extension Area

Existing Abattoir

Feeghroe Stream

Mullaghakaraun Bog

Banagher Town

PW-2

PW-1

Flood Plain

River Shannon

Alluvium

Peat

Till

Till

Till

Peat

Till

Karst

Waulsortian Fm

Lucan Fm

Lucan Fm [??]

Lucan Fm [??]

Karst along the gradational zone from Lucan Fm into Waulsortian Fm in North West of Site.

Fault zone identified in Banagher WSS Boreholes between 30-35 mbgl (Kelly, 2004).

Waulsortian Fm

Waulsortian Fm

NW-SE trending fault – it is likely a zone of enhanced permeability Is present around this fault where water is pulled from during pumping.

70
60
50
40
30
20
10
0
-10
-20
-30
mOD

0
1.0
2.0
3.0
4.0
5.0
6.0
Distance (km)

ATTACHMENT 11.3

MINEREX GEOPHYSICS SURVEY REPORT

MGX PROJECT NUMBER: 6415

BOHERADURROW

BANAGHER, CO. OFFALY

Boheradurrow

Banagher, Co. Offaly

Geophysical Survey

Report Status: Final

MGX Project Number: 6415

MGX File Ref: 6415f-005.doc

6th June 2019

Confidential Report To:

IE Consulting
Innovation Centre
Green Road
Carlow

Report submitted by :
Minerex Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Ireland
Tel.: 01-6510030
Fax.: 01-6510033
Email: info@mgx.ie

Issued by:

Author: John Connaughton (Geophysicist)

Reviewer: Hartmut Krahn (Senior Geophysicist)

Minerex
Geophysics Limited

Subsurface Geophysical Investigations

EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of EM31 ground conductivity, 2D-Resistivity and seismic refraction (p-wave) surveying for the ground investigation at a proposed development at Boheradurrow, Banagher, County Offaly.
2. The main objectives of the survey were to determine the ground conditions under the site, determine the depth to rock and the overburden thickness, to estimate the strength/stiffness/compaction of overburden and the rock quality, to map the extend of soft ground layers, to establish the presence of faults and fracture zones, and to detect possible karstified rock.
3. The seismic refraction and 2D-Resistivity profiles were positioned using the EM31 ground conductivity results.
4. The highest conductivity was found in the north corner of the site while the lowest conductivity was located on the higher ground in the middle of the site.
5. The seismic refraction data shows the elevation of the rock does not change much on site and indicated the higher ground on site is made up of sand and gravel rather than shallow rock.
6. The 2D-Resistivity shows a rock layer throughout the site with a relatively consistent elevation. There are a number of anomalous features within the rock layer which may indicate karst features.
7. The low resistivities at depth in the north corner of the site may be a large karst zone but may also be due to a change in rock type in this area.
8. Karst zones can be an issue for foundations as well as polluting surrounding ground water. They can also provide a good source of ground water for extraction.
9. Recommendations for targeted ground investigation are made.
10. This report will be reviewed and finalised after the complete direct ground investigation data has been received.

CONTENTS

List of Tables, Maps and Figures:

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey at a site in Boheradurrow, Co. Offaly. The survey consisted of EM31 ground conductivity, 2D-Resistivity and seismic refraction (p-wave) measurements. The survey was commissioned by IE Consulting.

The survey employed various geophysical methods that complement each other and improve the interpretation. The role of geophysics as a non-destructive fast method is to allow later targeted direct investigations. Those results can be used to improve the initial results and interpretation.

The proposed development is a meat processing plant with the main concerns being the depth to rock as well as any anomalies which may be geohazards or provide a source of groundwater for the plant.

At the time of the survey no proposed layout of the future plant was available.

1.2 Objectives

The main objectives of the geophysical survey were:

- To determine the ground conditions under the site
- To determine the depth to rock and the overburden thickness
- To estimate the strength/stiffness/compaction of overburden materials and the rock quality
- To determine the type of overburden and rock
- To detect lateral changes within the geological layers
- To map the extent of possible soft ground layers
- To determine the presence of possible faults and fracture zones
- To detect possible karstified zones within the rock

1.3 Site Description

The site is located in the east corner of the five cross roads junction, east of Banagher town. The site consisted of approx. 17.8 Ha of grass fields. Elevations of the site varied from 49.6 to 55.5 mOD. There was an old farm yard to the south of the site and an abattoir in the southeast corner. The soil was notably more peat rich in the northwest of the site. There was some standing water in the lower lying areas of the site, particularly in the west and northwest. Access was through a gate in the south and an ATV was used to transport equipment around the site.

1.4 Geology

The online bedrock geological map of Ireland (GSI, 2019) indicates that the survey area is underlain primarily by Waulsortian Limestone with the Lucan Formation being present in the southeast of the site. The overburden type varied from peat in the northwest to limestone till throughout most of the site.

There area a number of faults in the area which are generally running in a NW-SE direction although there are none noted within the survey area.

The nearest karst features noted on the maps is a swallow hole 1.4 km south of the site. There are also karst features a few kilometres to the northwest.

1.5 Report

This report includes the results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the results of the survey. More detailed descriptions of geophysical methods and measurements can be found in GSEG (2002), Milsom (1989) and Reynolds (1997).

The client provided a topographical map of the site and the digital version was used as the background map in this report. Elevations were surveyed on site and are used in the vertical sections.

The interpretative nature and the non-invasive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data, give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology consisted of using EM31 Ground Conductivity measurements to determine targets for 2D-Resistivity Profiling and Seismic Refraction Profiling. The seismic refraction profiles were primarily positioned to identify possible shallow rock on site while the 2D-Resistivity profiles were used to identify possible karst features or areas of interest for extracting groundwater.

The survey locations are indicated on Map 1. The profiles, locations, chainage and parameters are tabulated in Table 1.

All geophysical surveys are acquired, processed and reported in accordance with British Standards BS 5930:1999 +A2:2010 'Code of Practice for Site Investigations'.

Table 1: Geophysical Survey Locations and Acquisition Parameters

Profile Name	**Electrode/Geophone Spacing/m**	**Number of Electrodes/Geophones**	**Profile Length/m**
R1	5	128	635
R2	5	64	315
R3	5	64	315
R4	5	48	235
SUM			**1500**
S1 – S5	3	24	69
SUM			**345**

2.2 EM31 Ground Conductivity

The EM31 ground conductivity survey was carried out over the area indicated in Map 1 on lines nominally 10 m apart. Along each line a reading of ground conductivity was taken every second while walking along, thereby resulting in a survey grid of nominally 10 x 2 m. The locations were measured with a sub-meter accuracy SERES DGPS system attached to the EM31 and all data was jointly stored in a data logger. The conductivity meter was a GEONICS EM31 with Allegro data logger and NAV31 data acquisition software. The instrument was checked at a base station, the readings were stable and no drift occurred.

The conductivity is typical for certain geological material types. Dry and clean sand or gravel and most rock types (Granite, Sandstone and clean Limestone) have relatively low conductivities while peat, clay and clay-rich rock types (mudstone, shale) have high conductivities.

EM31 ground conductivity determines the bulk conductivity of the subsurface over a typical depth between 0 and 6 m bgl. and over a radius of approx. 5m around the instrument. When looking for clay, silt and water infill within rock occurring at relatively shallow depth the EM31 can find anomalous rock zones with a vertical extent of approx. 3 m. The measurements are disturbed by metal and other conductive objects within the range of the instrument and therefore no geological interpretations can be made in the vicinity of such man-made objects.

The survey was not carried out near the farm yard in the south of the site as the data would not be useable. It was noted on site that the small field behind the abattoir contained metal grids on the ground as well as possible reinforced concrete near the building. This accounts for the lows and highs in that field. High interference typically occurs along field boundaries and fences and this has been considered in the interpretation

2.3 2D-Resistivity

2D-Resistivity profiles were surveyed with electrode spacing of 5 m, up to 64 electrodes per set-up and a maximum length of 315 m per profile. The readings were taken with a Tigre Resistivity Meter, Imager Cables, stainless steel electrodes, laptop and ImagerPro acquisition software. Profiles R1 which was longer than 315m was carried out in roll-along mode to produce one continuous profile for the report.

During 2D-Resistivity surveying data is acquired in the form of linear profiles using a suite of metal electrodes. A current is injected into the ground via a pair of electrodes while a potential difference is measured across a second pair of electrodes. This allows for the recording of the apparent resistivity in a two-dimensional arrangement below the profile. The data is inverted after the survey to obtain a model of subsurface resistivities. The generated model resistivity values and their spatial distribution can then be related to typical values for different geological materials.

2D-Resistivity has previously proven zones of anomalous or karstified rock with lateral extents of 5 m and more.

2.4 Seismic Refraction

Seismic refraction profiles were surveyed with geophone spacing of 3 m and 24 geophones per set-up resulting in a 69 m length per set-up. The recording equipment consisted of a 24 Channel GEOMETRICS ES-3000 engineering seismograph with 4.5 Hz vertical geophones. The seismic energy source consisted of a

hammer and plate. A zero delay trigger was used to start the recording. Normally 7 shot points per p-wave profile were used.

In the seismic refraction survey method a p-wave is generated by a source at the surface resulting in energy travelling through surface layers directly and along boundaries between layers of differing seismic wave velocities. Processing of the seismic data allows geological layer thicknesses and boundaries to be established.

Seismic Refraction generally determines the depth to horizontal or near horizontal layers where the compaction/strength/rock quality changes with an accuracy of 10 – 20% of depth to that layer. Where low velocity layers or shadow zones are present (e.g. below solid ground surface) or where layers dip with more than 20 degrees angle the accuracy becomes much less.

2.5 Site Work

The data acquisition was carried out between the 11th and 14st of February 2019. The weather conditions were variable throughout the acquisition period. Health and safety standards were adhered to at all times. The locations and elevations were surveyed with a TRIMBLE RTK-GPS to accuracy < 0.05 m.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was carried out utilising the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site, and the experience of the authors.

There are separate interpretations for the seismic refraction and 2D-Resistivity as they were generally carried out in separate locations. The Seismic refraction interpretation uses seismic velocities to determine the strength, compaction or quality of the overburden and rock while the 2D-Resistivity interpretation provides information on overburden types and features within the rock as well as an approximate depth to rock. The EM31 provides an overview of the changes in the near surface geology, particularly where shallow rock or clay or peat overburden is to be expected.

Map 3 is an interpretation map using all the available information. It highlights different karst features as well as areas where the overburden consists mainly of sand and gravel. Recommendations for targeted ground investigations are also shown on this map.

3.1 EM31 Ground Conductivity

The EM31 ground conductivity values were merged into one data file for each survey area and contoured and gridded with the SURFER contouring package. The contours are created by gridding and interpolation and care must be taken when using the data. The contour map is overlaid over the location and base map (Map 2) and the values in milliSiemens/metre (mS/m) are indicated on the colour scale bar.

Low conductivities indicate either shallow bedrock or dry sandy and gravely overburden while higher conductivities indicate deeper bedrock, zones of peat and clay-rich overburden. The results show the lowest conductivity occurs on the higher ground on site. This would indicate either shallower rock or more sand and gravel in the overburden. The low seismic velocities to a depth of 6 m indicate the higher ground contain sand and gravel rather than shallow rock. The highest conductivity readings are found in the north of the site where the soil is notably more peat rich.

3.2 2D-Resistivity

The 2D-Resistivity data was positioned and inverted with the RES2DINV inversion package. Roll-along profiles were concatenated for a joint inversion. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface model resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available and for this project the Jacobian Matrix was recalculated for the first three iterations, then a Quasi-Newton approximation was used for subsequent iterations. Each dataset was inverted using seven iterations resulting in a typical RMS

error of <3.0%. The resulting models were colour contoured with the same resistivity scale for all profiles and they are displayed as cross sections (Figures 1a).

Resistivities are characteristic for certain overburden and rock types. If there is a high content of clay minerals (which are electrically conductive) then the overburden resistivity will be lower than if there is a high content of clastic grains like sand or gravel. The purer the clay and the lower the sand/gravel content the lower the resistivity. The water content in the overburden also influences the resistivities but generally the clay content has a larger effect.

Within bedrock types like clean limestone, high resistivities indicate a fresh strong unweathered rock. As the weathering in the rock increases the resistivity gets lower because of weathering products, remineralisation of rock and infill of cracks, faults and voids with clay and water. Weathering within rock is typically indicated by lower resistivity values in the cross sections.

In limestone areas karstified rock is defined in this report as a formerly intact clean limestone rock, liable to karstification, that has been partially dissolved by water over long geological time scales and where the cavities and voids have either remained empty (filled by air) or became filled by overburden sediment (clay, silt, sand), weathering product of the broken rock itself or water. This process would lead to a reduction of the resistivity of the overall rock and therefore karstified rock has a lower resistivity than intact clean limestone rock. This is generally indicated by lower resistivities embedded within high resistivity at depth.

The resistivities cover a range typical for materials from clay rich overburden or peat (low resistivities) to fresh strong unweathered bedrock (high resistivities). The ranges have been taken into the consideration for the interpretation. Low resistivity values (<250 Ohmm) typically indicate peat or sandy gravelly clay or silt overburden. Where this layer occurs at depth it has been interpreted as highly karstified limestone. Medium values (250 to 1000 Ohmm) shows a clayey silty sand/gravel overburden or very weathered or karstified limestone. High resistivities (>1000 Ohmm) indicate bedrock types like clean limestone.

Overall the depth to rock does not vary greatly throughout the site, however there are some strong anomalies within the rock layer. The largest of these are in the north corner of the site as can be seen at the start of profile R3 and the end of profile R4. The sharp drop in lateral resistivities at depth indicate a strong weathering of the limestone bedrock rather than a substantial thickening of the overburden layers. Profile R1 shows a number of smaller anomalous areas within the rock layer, particularly at distances of 160m, 360m, 415m and 500. Along profile R2 there is one anomalous zone within the rock at Ch140. This may be part of a linear feature as shown on map 3.

Table 2: Summary of Results and Interpretation (Resistivity only)

Layer	General Resistivity Range (Ohmm)	Interpretation
A1	<250 and shallow	Peat, sandy gravelly Clay or Silt Overburden
A2	<250 and deep	Highly karstified Limestone
B1	250 - 1000 and shallow	Clayey silty Sand or Gravel Overburden or very weathered Rock
B2	250 - 1000 and deep	Karstified Limestone
C	>1000	Fresh Limestone

3.3 Seismic Refraction

The seismic refraction data was positioned and processed with the SEISIMAGER software package to give a layered model of the subsurface. The numbers of layers has been determined by analysing the seismic traces and 3 layers were used in the models. All seismic profiles were subject to a standardised processing sequence which consisted of a topographic correction which was based on integrated elevation data, first break picking, tomographic inversion, travel-time computation via ray-tracing and velocity modelling. Residual deviations of typically 0.4 to 1.8 msec RMS have been obtained for each profile. Following each processing stage QC procedures were adhered to. The resulting layer boundaries are shown as thick lines on the cross sections (Figure 1b). The average seismic velocities obtained within the layers are annotated on the sections as bold black numbers.

The p-wave seismic velocity is closely linked to the density of subsurface materials and to parameters like compaction, stiffness, strength and rock quality. The higher the density of the subsurface materials the higher the seismic velocity. Similarly for the other parameters it is generally valid that a more compacted, stiffer and stronger material will have a higher seismic velocity. For rock, the seismic velocity is higher when the rock is stronger, less weathered and has a higher quality. If the rock is more weathered, broken, fractured, fissured or karstified then the seismic velocity will be reduced compared to that of intact fresh rock.

Because of the above relation the seismic refraction method and seismic velocities are suitable to investigate ground where the layers get denser, more compacted and stronger with depth. A disadvantage is that some materials may have the same seismic velocity: Very stiff to hard or very dense highly consolidated overburden and a weathered rock can have the same seismic velocity range.

The modelled seismic data has created the following layered ground model:

Layer 1 has a thickness of up to 1.75 m and seismic velocities of 350 - 400 m/s. This overburden would be topsoil and soil with a soft or loose stiffness or compaction.

Layer 2 was modelled with a velocity range of 900 - 1600 m/s and has a thickness of between 2.25 and 7.25 m. The velocity indicates overburden material with firm to stiff or medium dense to dense strength or compaction. This layer may also contain highly weathered rock, particularly at its base. This layer could be extracted through digging and ripping..

Strong rock is indicated by seismic velocities of >5000 m/s and the top of this strong rock is at an elevation of between 45.5 and 49 m throughout the site. This layer would require breaking and blasting if it is to be removed.

The seismic refraction results do not indicate any great changes in the thickness and depth of Limestone layer throughout the site. Generally the seismic refraction good limestone layer is a similar depth to the clean Limestone layer in the 2D-Resistivity interpretation.

Table 3: Summary of Results and Interpretation (Seismic Refraction Only)

Layer	**General Seismic Velocity Range (m/sec)**	**Stiffness/ Compaction or Rock Strength/ Quality**	**Interpretation**	**Estimated Excavation Method**
1	35 - 400	Soft or Loose	Peat or Organic Matter	Diggable
2	900 - 1600	Firm to stiff or Medium Dense to dense Or very poor	Overburden or highly weathered Rock	Diggable or rippable
3	5000	Good to very good rock	Strong competent Limestone	Breaking & Blasting

4. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made:

- Minerex Geophysics carried out a survey consisting of EM31 ground conductivity, 2D-Resistivity and seismic refraction profiling.
- The EM31 ground conductivity results show the lowest conductivity occurring on the higher ground in the middle of the site. When compared with the seismic refraction velocities, this area is interpreted as containing a sand and gravel overburden. The highest conductivity (peat/clay overburden) are found in the north corner of the site.
- The seismic refraction data was modelled using a three layer model ranging from soft or loose overburden to good to very good rock. The depth to the rock layer varies between 4 and 8.5m below ground level.
- The resistivity shows a similar depth to rock throughout the site while also identifying anomalies within the rock layer, the largest of these anomalies are found in the north corner of the site which can be seen along profiles R3 and R4
- **Soft Ground:** The softest ground is most likely in the north corner of the site where the highest ground conductivity and lowest resistivities occur.
- **Depth to Rock:** Strong, good and fresh rock occurring at a similar depth throughout the survey area. According to the seismic refraction results, the shallowest rock occurs in the west of the site along profiles S4 and S5. The depth to rock from the surface varied between 3.75 and 8.25 m which corresponds to elevations of between 45.5 and 49 mOD.

  Seismic refraction Profiles S2 and S3 and 2D-Resistivity profile R3 indicate that the higher ground on site is made up primarily of sand and gravel rather than due to shallow rock. Trial pits could be carried out on the higher ground to determine its makeup. If it is sand and gravel, this material could be of good use elsewhere on site.

  Overall the elevation to rock does not vary greatly on site and it would be assumed therefore that the shallowest rock on site would be found at the lowest elevations. Minerex does not have the proposed building plans however it would be recommended to carry out trial pits and possibly trial breaking of rock in areas where excavations will be required to assess the depth to rock.
- **Possible Karst Zone:** The existence of karstified rock could lead to subsidence of overburden, especially if the water drainage regime is altered The most substantial potential karstified is located in the north corner where the resistivities decreased significantly along profiles R3 and R4 This change in resistivity may also be due to a change in rock type to an argillaceous limestone or shale.

There are a number of other notable anomalies which occur along profiles R1 and R2. Two of these features at a distances of 415m along Profile R1 and 140m along Profile R2 are interpreted as a linear karst feature on Map 3. Other notable anomalies are found along profile R1 including at distances of 160m, 360 and 500, however these anomalies do not occur along profile R2.

- **Ground Water:** Karstified rock can provide targets for ground water extraction, particularly where there is not substantial clay infill. There are a number on areas of anomalous rock which may provide good targets for extracting ground water. The proposed layout plans for the site should also be taken into account when considering the location of a well.
- Map 3 is an interpretation map which uses all the results from the survey. The areas highlighted include possible karst features and where sand and gravel overburden occurs.
- Recommendation have been made below targeting area of concern relating to soft ground, shallow rock, karst zones and ground water extraction.
- The recommendations below should not preclude any other site investigation that may be carried out based on geological, geotechnical or engineering considerations.
- The interpretation presented here should be reviewed once any additional geotechnical data becomes available.

Table 4: Recommendations for Targeted Ground Investigation

Name	Location	Test	Reason
TP1	603862, 713757	Trial Pit to assess the depth of soft ground	To target a zone of locally reduced resistivities and high conductivity
TP2	603998, 713632	Trial Pit to levelling/required excavation depth	At assess the excavatability of the higher ground on site
TP3	603700, 713611	Trial Pit to levelling/required excavation depth	To determine the depth of diggable material
RC1	603867, 713710	Rotary Core Hole to 20 m or Test Well	To determine rock type and quality and assess feasibility of pumping water
RC2	603982, 713384	Rotary Core Hole to 20 m or Test Well	To determine rock type and quality and assess feasibility of pumping water

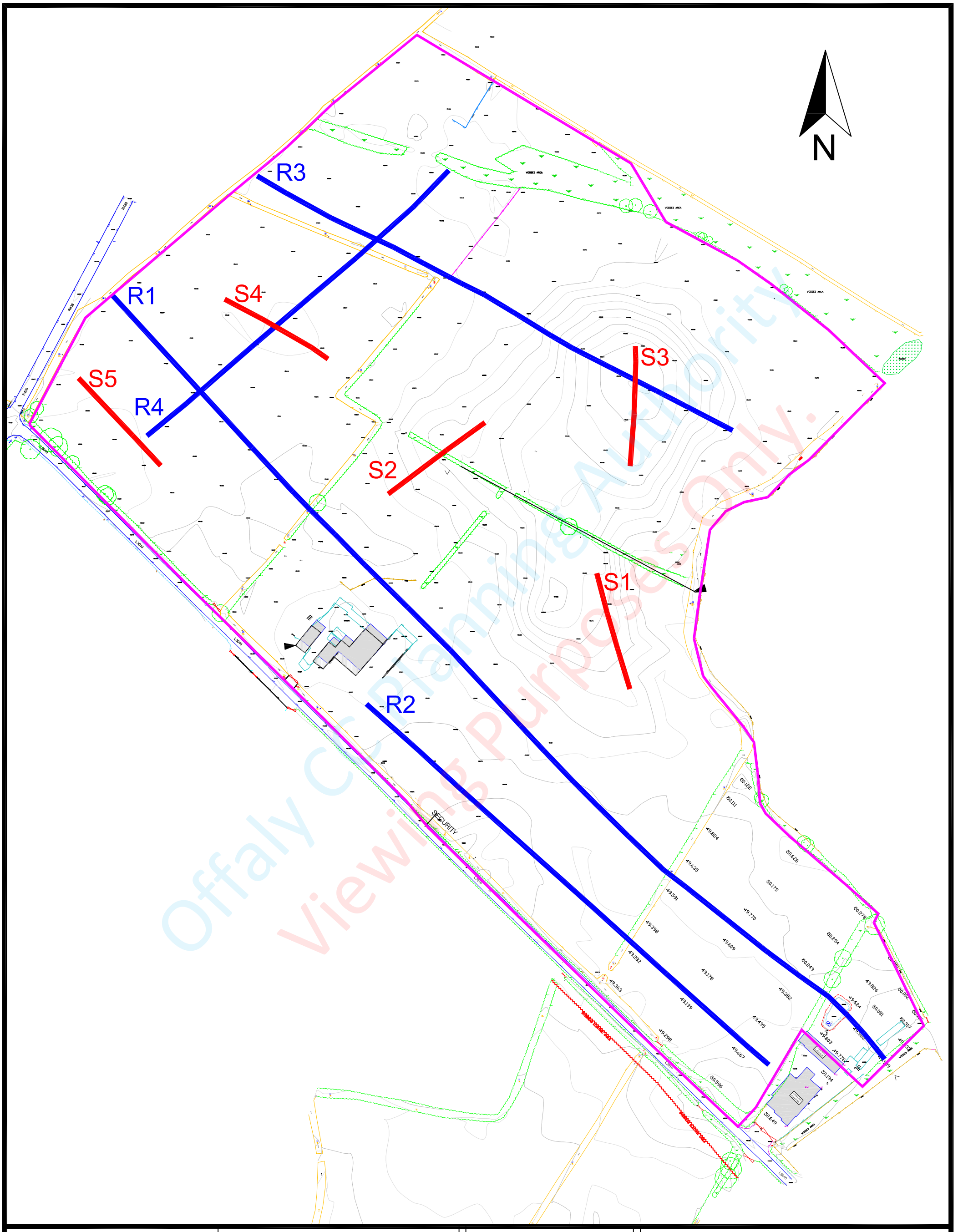
5. REFERENCES

1. **GSEG 2002.** Geophysics in Engineering Investigations. Geological Society Engineering Geology Special Publication 19, London, 2002.

2. **GSI, 2019.** Online Bedrock Geological Map of Ireland. Geological Survey of Ireland 2019.

3. **Milsom, 1989.** Field Geophysics. John Wiley and Sons.

4. **Reynolds, 1997.** An Introduction to Applied and Environmental Geophysics. John Wiley and Son.



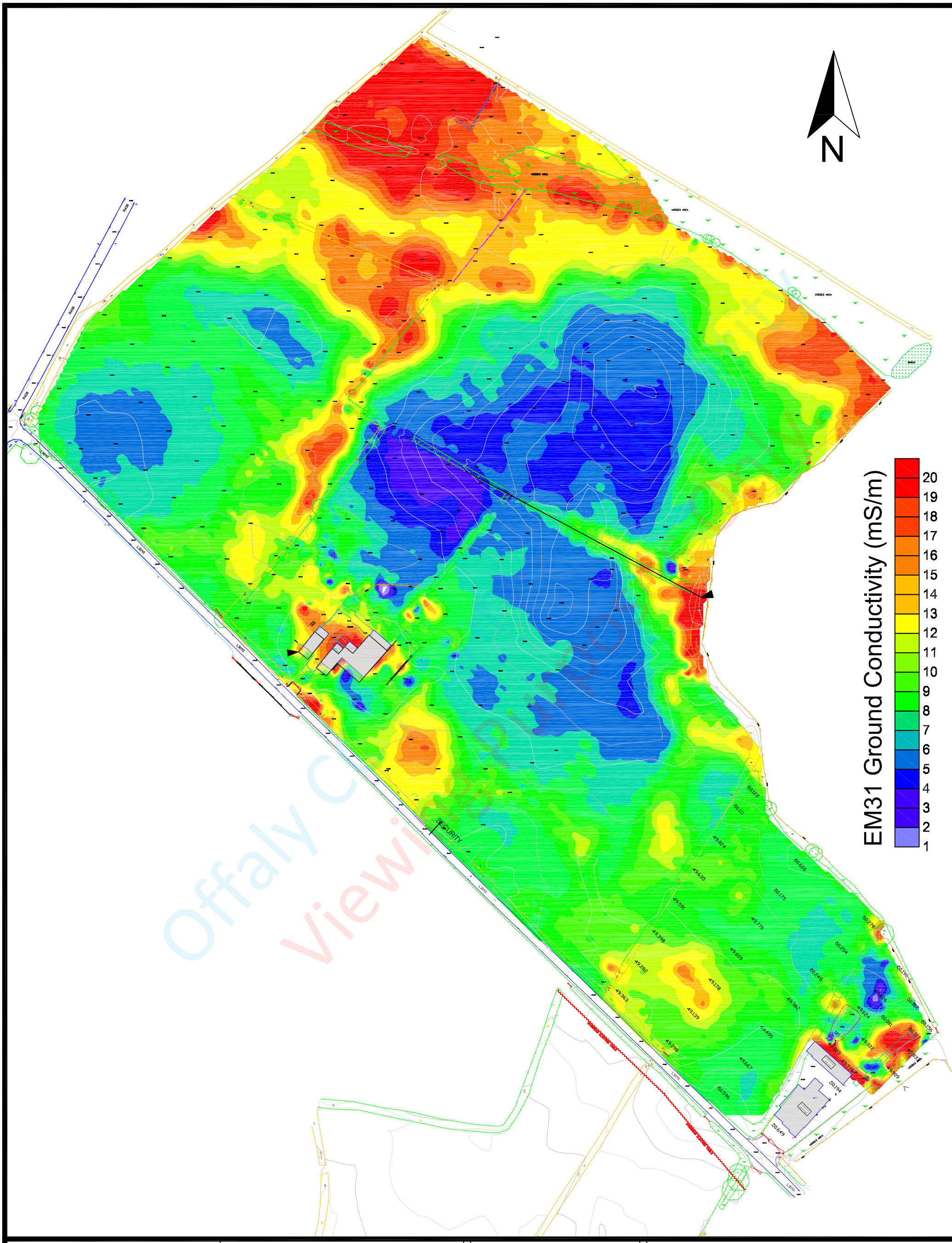
Minerex
Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

CLIENT	IE Consulting
PROJECT	Boheradurrow, County Offaly Geophysical Survey
TITLE	Map 1: Geophysical Survey Location Map

SCALE:	1:2000 @ A3
PROJECT:	6415
DRAWN:	JC
DATE:	18/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

LEGEND: Geophysical Survey Locations:

- R2 — 2D-Resistivity Profile
- S1 — Seismic Refraction Profile
- EM31 Survey Area



Minerex Geophysics Limited

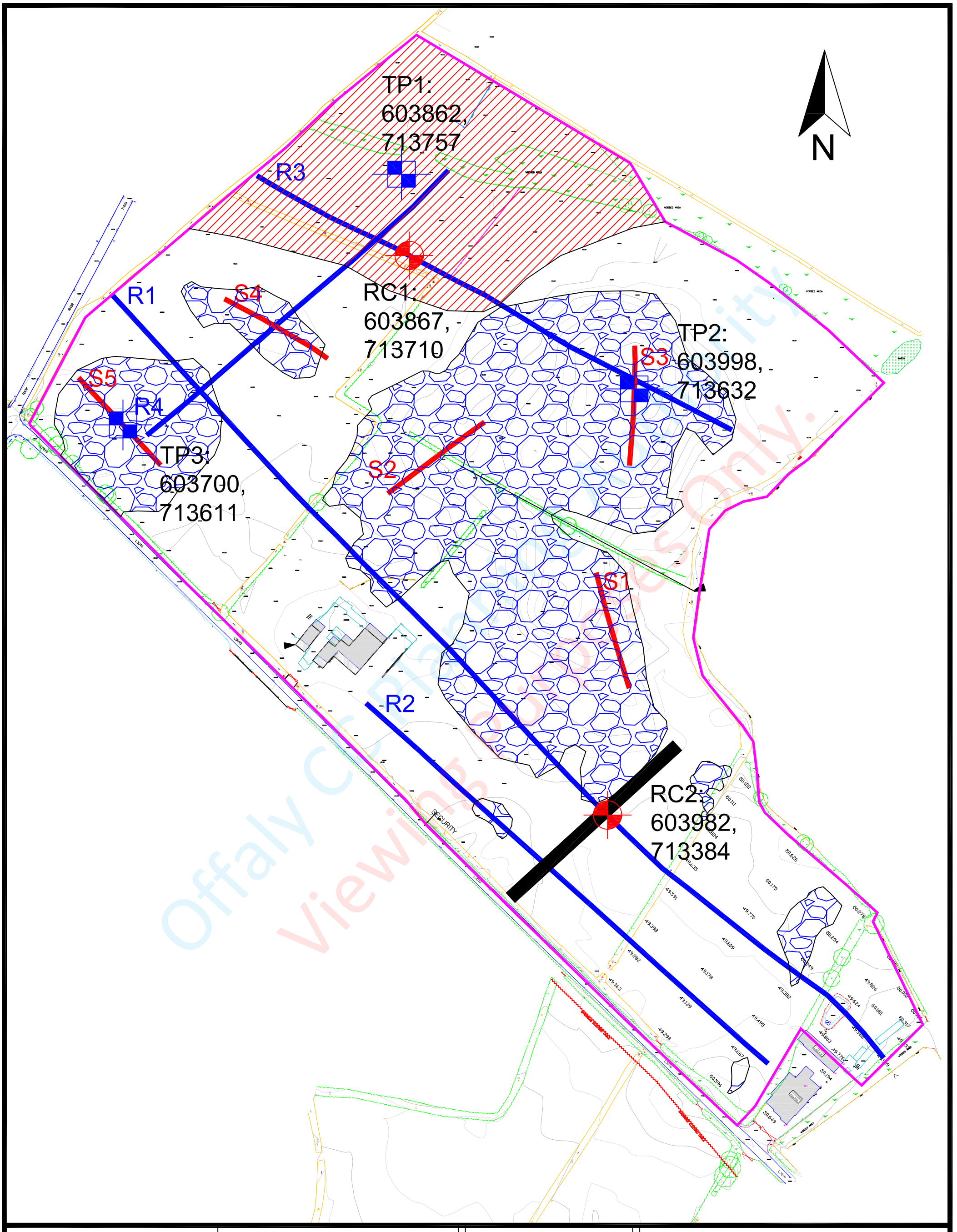
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

CLIENT	IE Consulting
PROJECT	Boheradurrow, County Offaly Geophysical Survey
TITLE	Map 2: EM31 Ground Conductivity Contour Map

SCALE:	1:2000 @ A3
PROJECT:	6415
DRAWN:	JC
DATE:	18/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

LEGEND:

The colour contour map shows the EM31 ground conductivity in mS/m with the colour scale bar indicated.



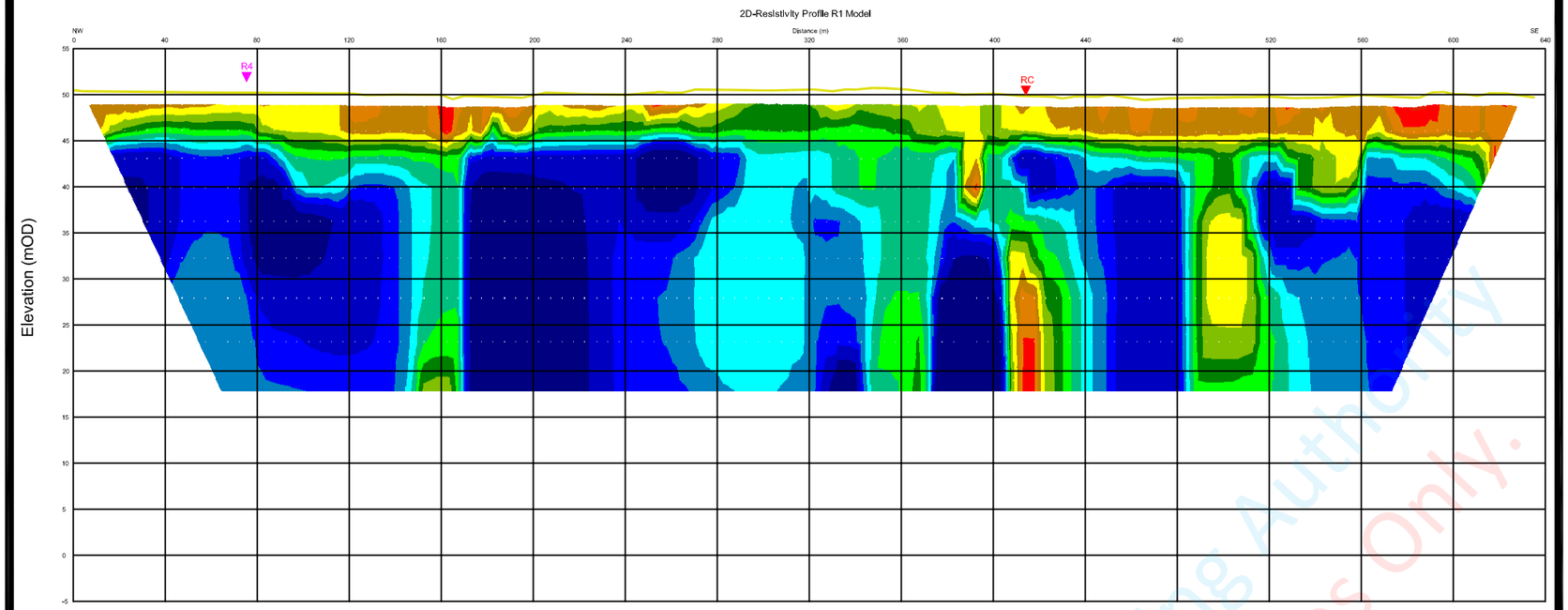
Minerex
Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

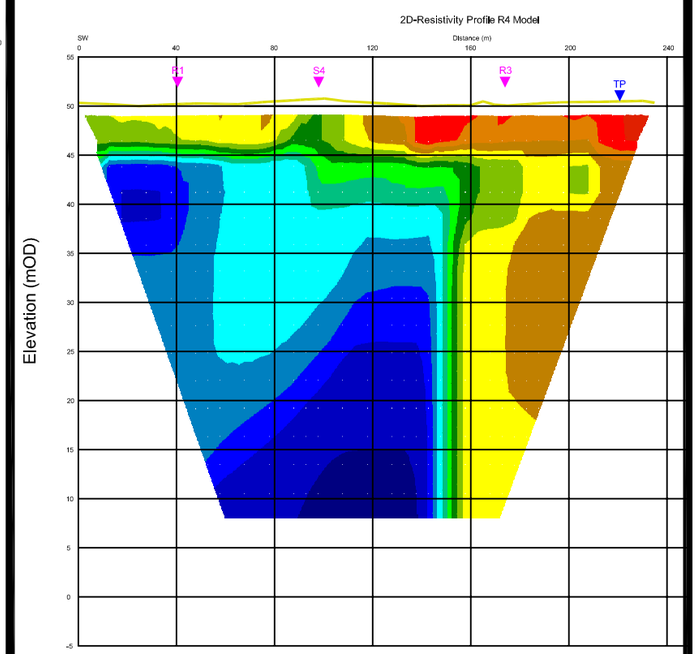
CLIENT	IE Consulting
PROJECT	Boheradurrow, County Offaly Geophysical Survey
TITLE	Map 3: Geophysical Survey Interpretation Map

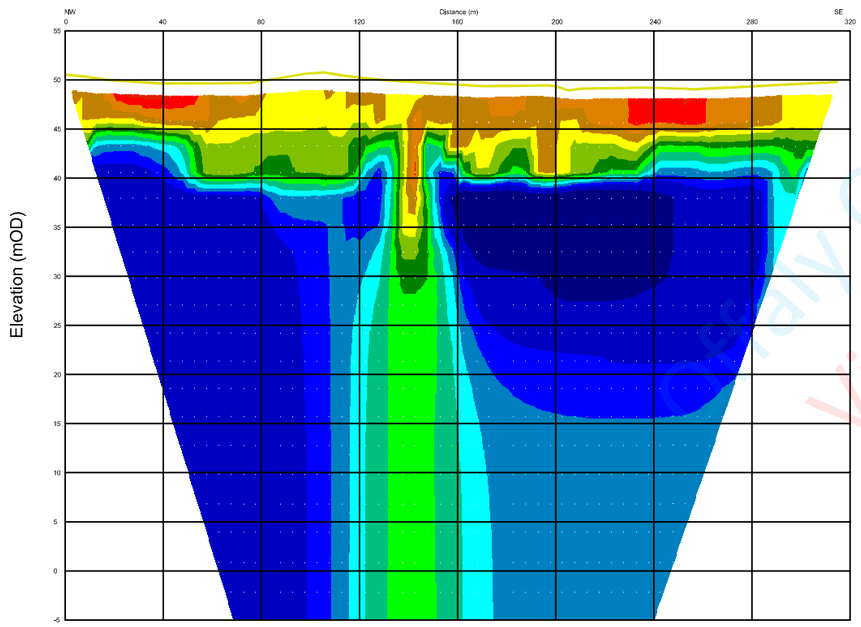
SCALE:	1:2000 @ A3
PROJECT:	6415
DRAWN:	JC
DATE:	18/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

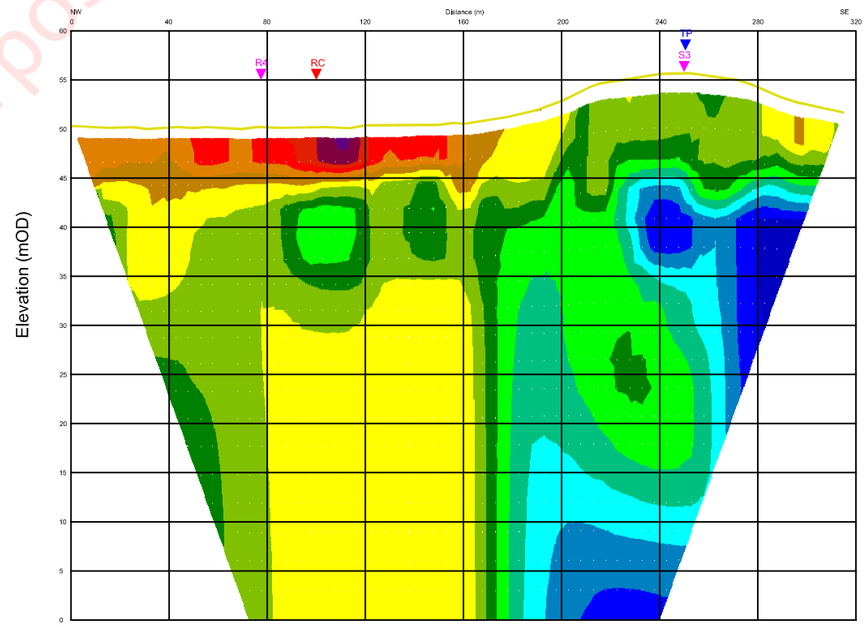
LEGEND: Geophysical Interpretation:

- Sand and Gravel Overburden
- Karstified Limestone or Argallicious Limestone or Shale
- Linear Karst Feature
- RC1 — Proposed Rotary Core Hole or Test Well
- TP1 — Proposed Trial Pit









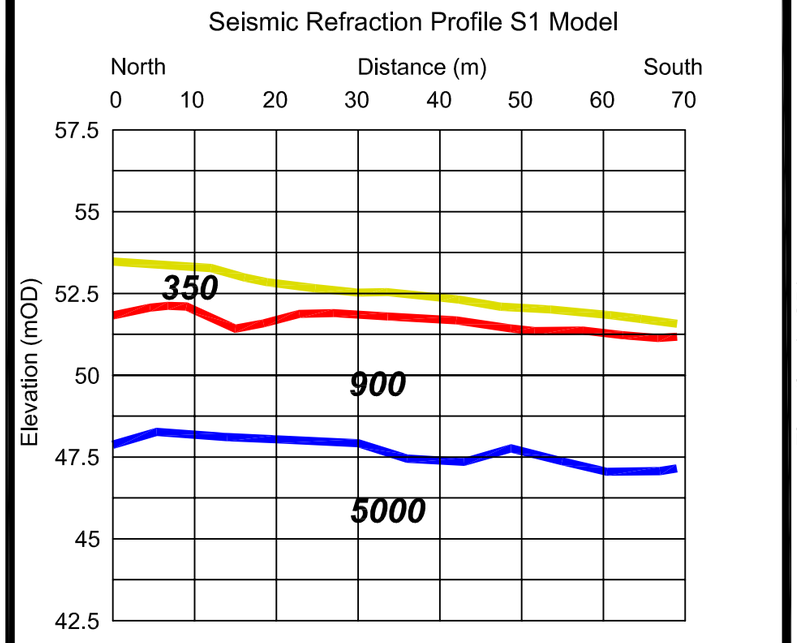
Minerex
Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

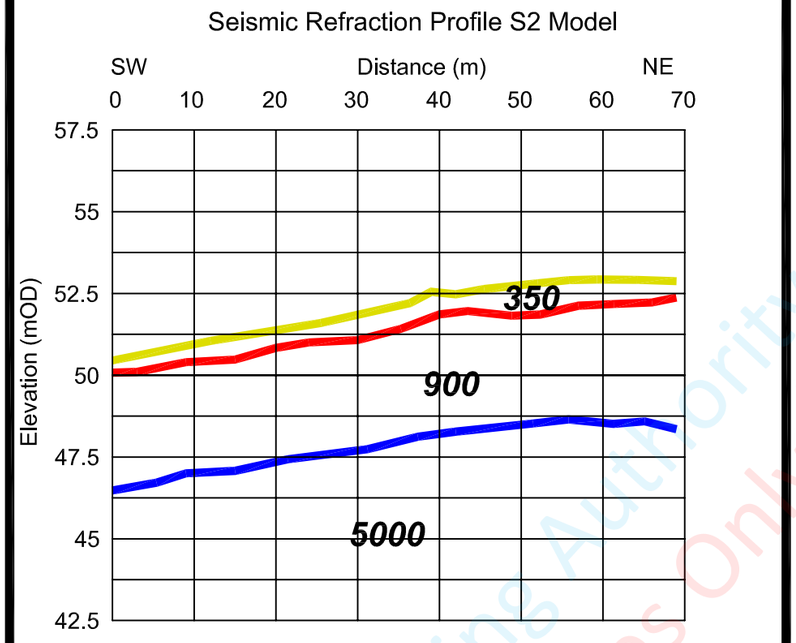
CLIENT	IE Consulting
PROJECT	Boheradurrow, Banagher Geophysical Survey
TITLE	Figure 1a: Models of 2D-Resistivity Survey

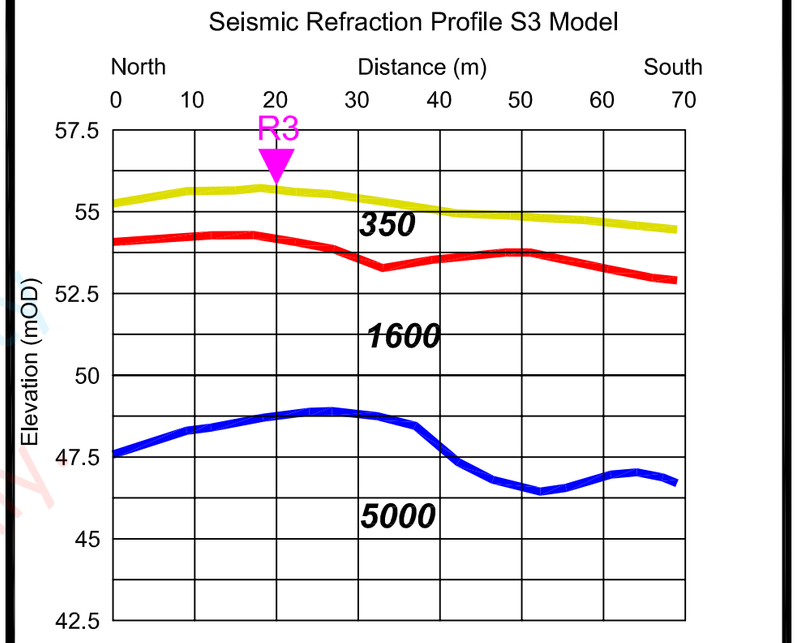
SCALE:	1:2500 @ A3, VE x 4
PROJECT:	6415
DRAWN:	JC
DATE:	20/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

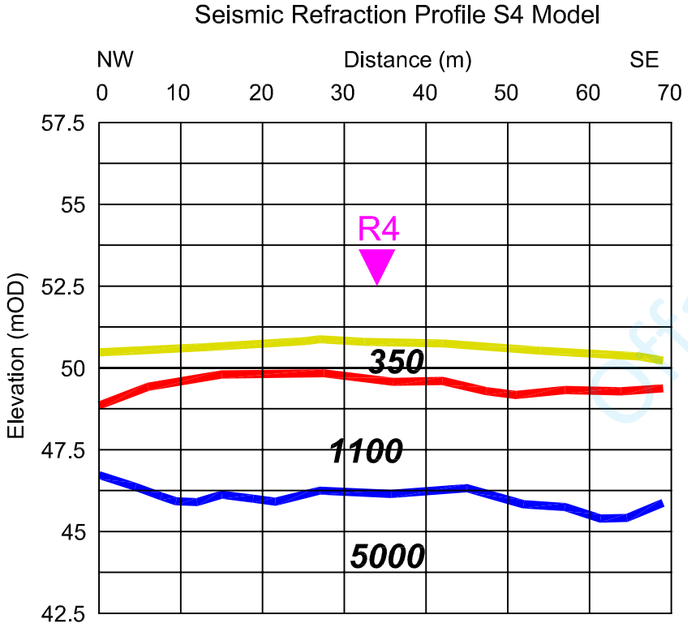
LEGEND: 2D-Resistivity Model Values:

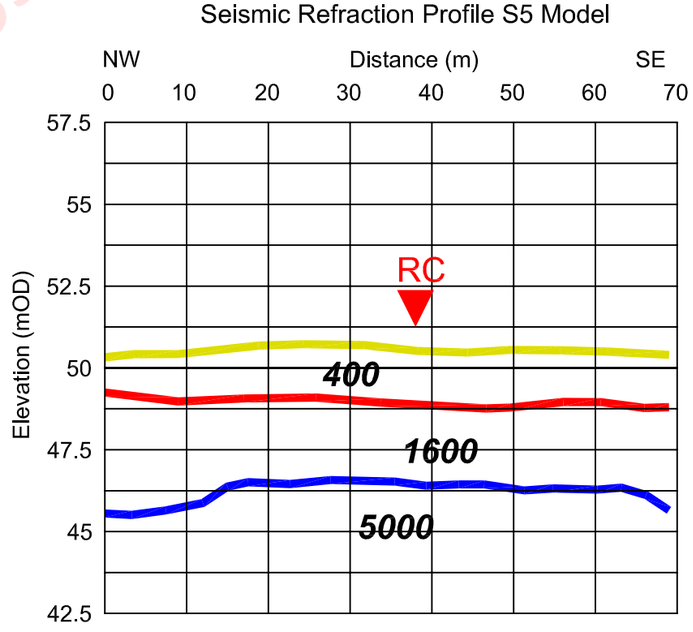
Resistivities (Ohmm) for 2D-Resistivity Model









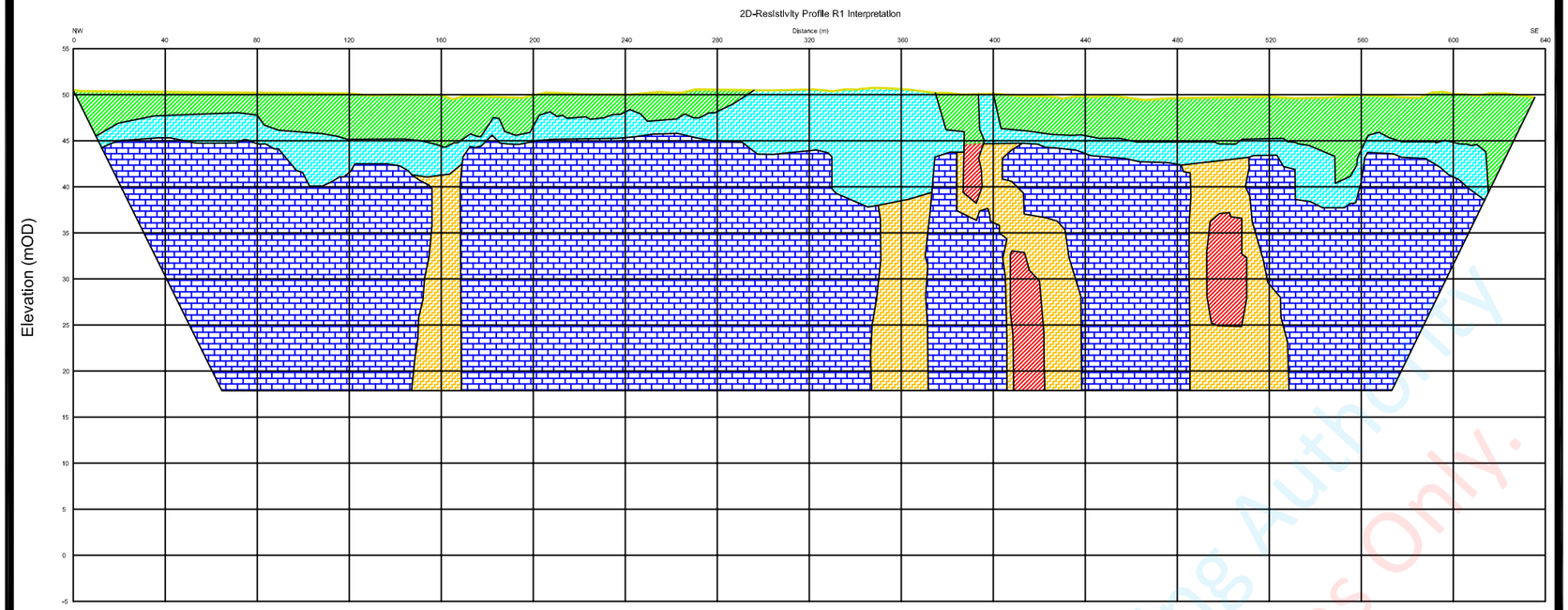


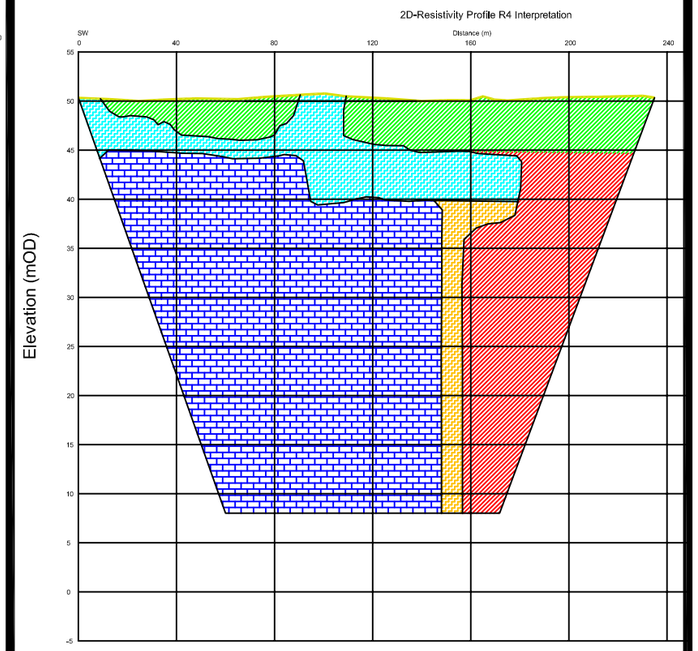
Minerex
Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

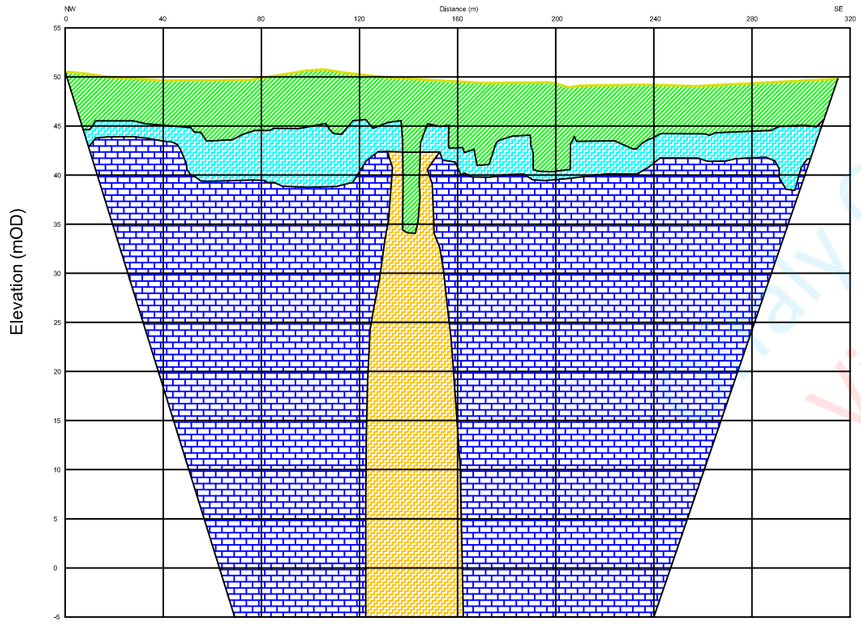
CLIENT	IE Consulting
PROJECT	Boheradurrow, Banagher Geophysical Survey
TITLE	Figure 1b: Models of Seismic Refraction Survey

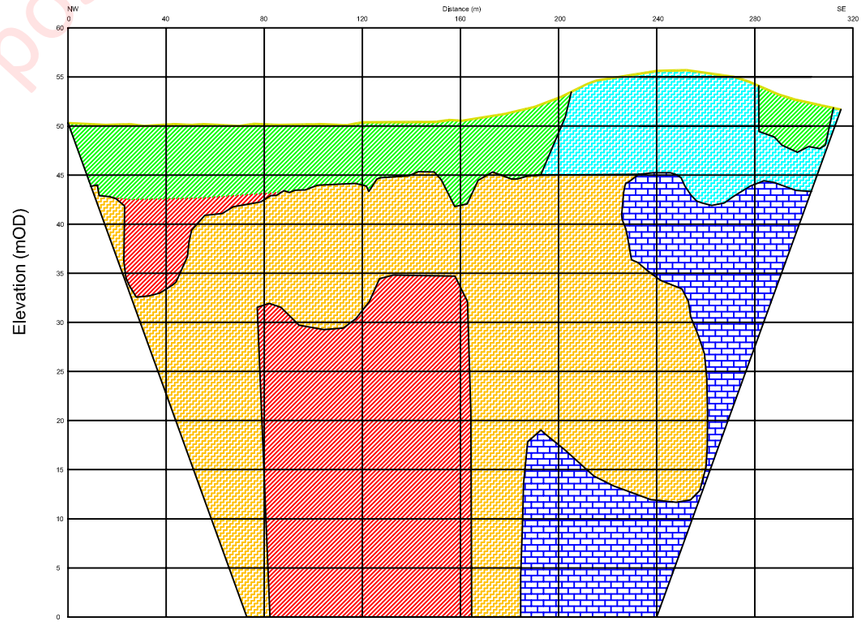
SCALE:	1:750 @ A3, VE x 4
PROJECT:	6415
DRAWN:	JC
DATE:	20/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

LEGEND:
Layers from Seismic Refraction Model:
Ground Surface/Top of Layer 1 (350 - 400 m/s)
Top of Layer 2 (900 - 1600 m/s)
Top of Layer 3 (5000 m/s)
1800 Seismic Velocity in m/s









Minerex
Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

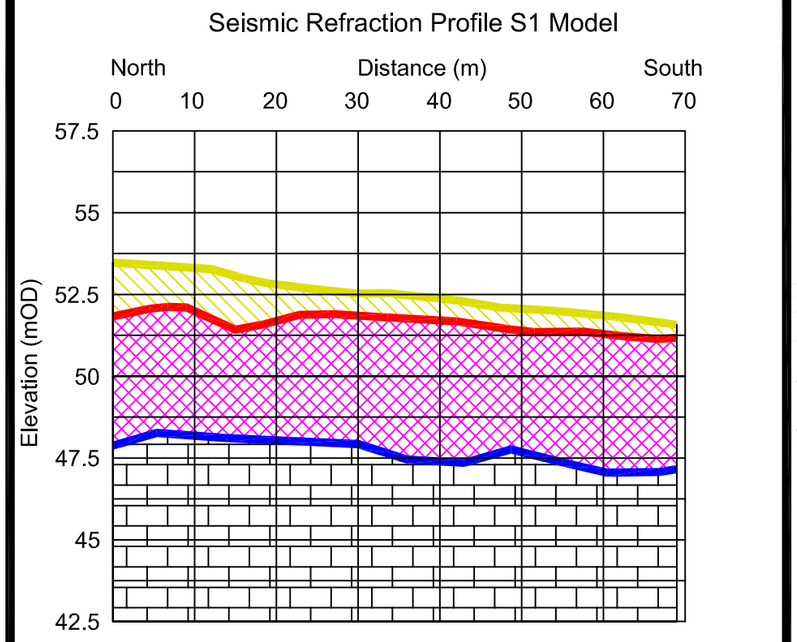
CLIENT	IE Consulting
PROJECT	Boheradurrow, Banagher Geophysical Survey
TITLE	Figure 2a: Interpretation of 2D-Resistivity Survey

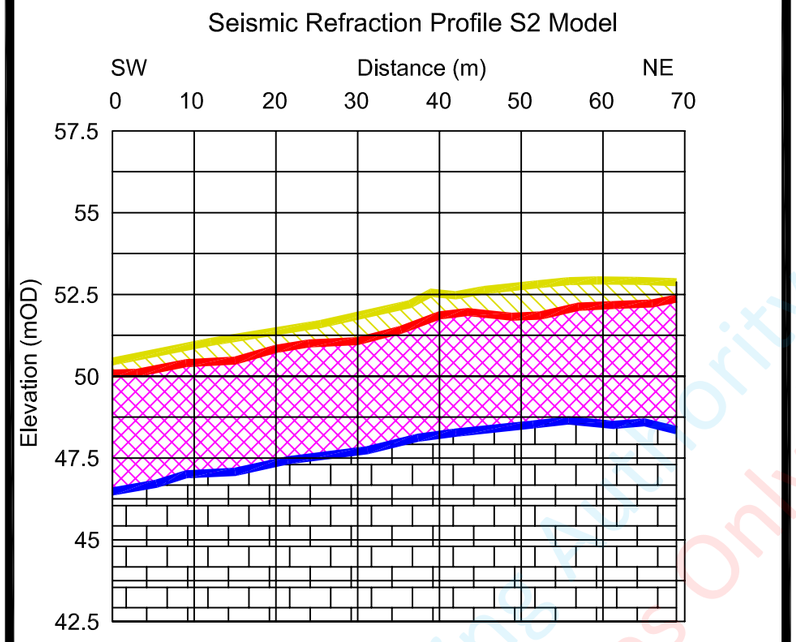
SCALE:	1:2500 @ A3, VE x 4
PROJECT:	6415
DRAWN:	JC
DATE:	20/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

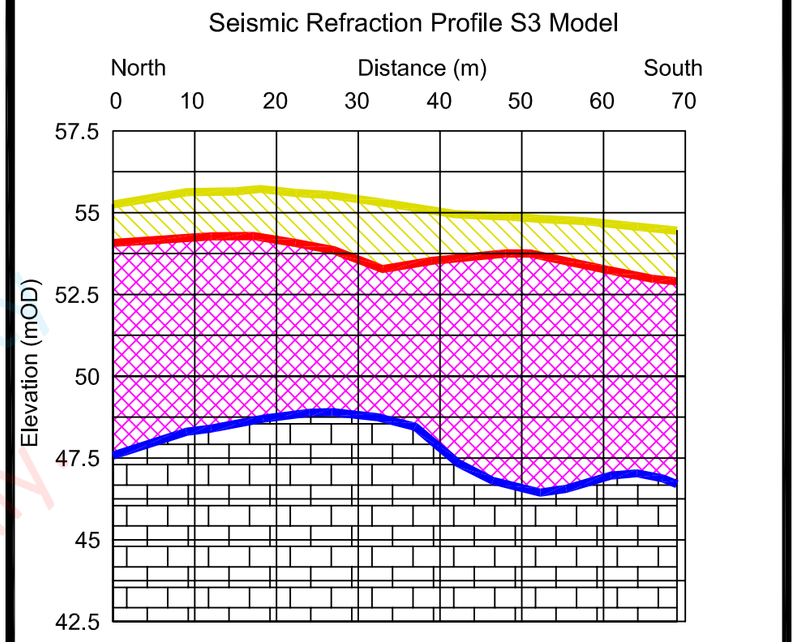
LEGEND:

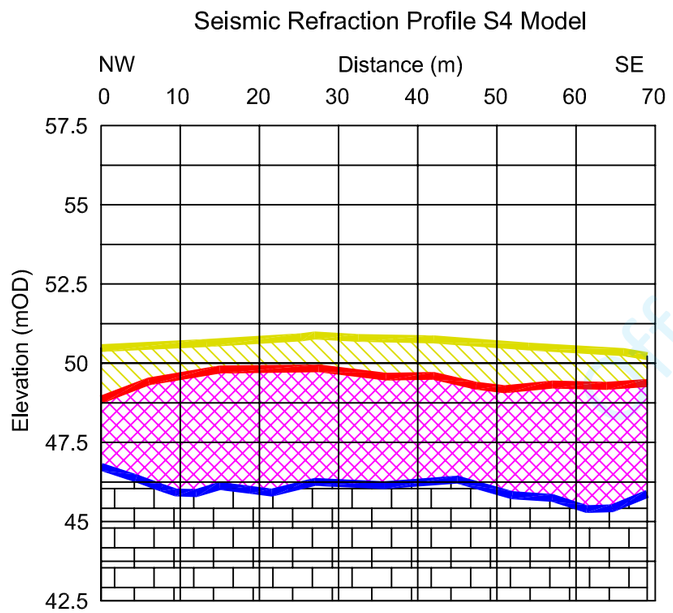
Interpretation (2D-Resistivity):

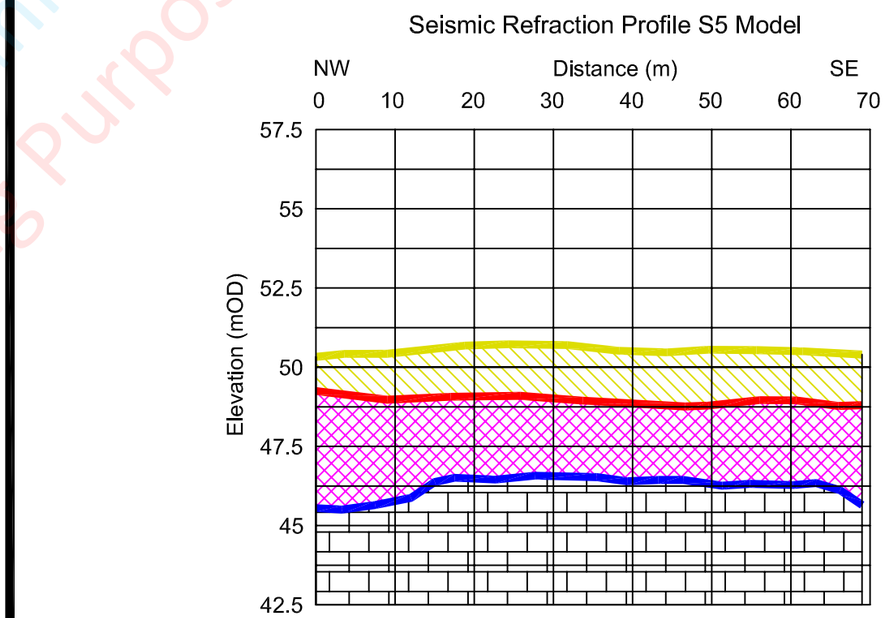
- A1 Peat, sandy gravelly Clay or Silt
- A2 Highly karstified Limestone
- B1 Clayey silty Sand or Gravel or very weathered Rock
- B2 Karstified Limestone
- C Fresh clean Limestone











Minerex
Geophysics Limited
Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Fax. (01) 6510033
Email: info@mgx.ie
Web: www.mgx.ie

CLIENT	IE Consulting
PROJECT	Boheradurrow, Banagher Geophysical Survey
TITLE	Figure 2b: Interpretation of Seismic Refraction Survey

SCALE:	1:750 @ A3, VE x 4
PROJECT:	6415
DRAWN:	JC
DATE:	20/2/2019
MGX FILE:	6415f_MapsFigs.dwg
STATUS:	Final

LEGEND:

Interpretation (Seismic Refraction):

1 Soft or loose Overburden

2 Firm to stiff or medium dense to dense Overburden or Highly Weathered Rock

3 Good to very good Limestone